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OFFICE OF EXPERIMENT STATIONS—BULLETIN 222.

A. C. TRUE, Director.

IRRIGATION IN TEXAS.

BY

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PREPARED UNDER THE DIRECTION OF

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., October 4, 1909.

Sir: I have the honor to transmit herewith a report on irrigation in the State of Texas, prepared by J. C. Nagle, professor of civil engineering, Agricultural and Mechanical College of Texas, under the direction of Samuel Fortier, chief of irrigation investigations of this Office. This is one of a series of reports giving the status of irrigation in the several arid States at the time they were prepared. This report on Texas is based on data collected in 1908, and refers to that year. Development has been rapid since that time, and conditions in some sections have changed since the report was prepared. There is a very large call upon this Office for general information regarding the opportunities for settlement on irrigated lands, the cost of land and water and of establishing homes on these lands, and regarding the crops grown. The attempt has been made to include in each of these reports as nearly as possible all the information which will be needed by persons contemplating settlement in the State to which it refers. It is recommended that the report be published as a bulletin of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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IRRIGATION IN TEXAS.

GENERAL DESCRIPTION.

Texas lies in the extreme southern part of the Great Central Plain. Its area is 265,896 square miles, or 170,173,440 acres, nearly one-ninth of the total area of continental United States, excluding Alaska. States the size of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, and South Carolina could be carved out of it and there would still remain an area equal to one-third that of Pennsylvania. The State extends through 9.5° of latitude and nearly 13° of longitude. Texline, located 10 miles south of the northern boundary, is only 50 miles south of Cairo, Ill., while Brownsville, 800 miles farther south, near the extreme southern part of the State, is in the same latitude as Miami, Fla. The eastern boundary of the State is but a few miles west of the meridian passing just east of St. Paul, Minn., while El Paso, 750 miles west and near the extreme western part of the State, is nearly 100 miles west of Denver and on approximately the same meridian as Glasgow, Mont. (Pl. I.)

There are 245 counties in the State, the smallest, Rockwall, having an area of only 143.75 square miles, while El Paso, the largest, has an area of 9,280 square miles, or more than seven and one-half times that of the State of Rhode Island.

According to the census of 1900, Texas had a population of 3,048,710 and ranked sixth among the States. The average population per square mile was 11.6 as compared with 25.6 for the United States, or 129.8 for the North Atlantic States. The population of the State by the censuses since 1850 is as follows:

Population of Texas by United States Census, 1850–1900.

Year.	Population.	Year.	Population.
1850	212,592	1880	1,591,749
1860	602,215	1890	2,235,527
1870	818,579	1900	3,048,710

Prof. F. M. Bralley, general agent of the conference of education in Texas, estimated the population in 1906 as 3,536,618, and it is

expected that by the next census it will have reached 4,000,000. In bringing about this increase, irrigation and intensive cultivation are to play an important part. They have already rendered profitable large areas which up to a few years ago were considered worthless for agricultural purposes.

TOPOGRAPHY.

Texas has a frontage of 400 miles on the Gulf of Mexico, and slopes back to the north and west to elevations of 4,000 to 9,500 feet. The following are the highest points in the State:

Elevations of points in Texas.

Name.	Feet.
Guadalupe Peak, El Paso County	9,500
Mount Emery, Brewster County	9,000
Mount Livermore, Jeff Davis County	8,400
Paisano, on the Southern Pacific Railroad, 700 miles west of Beaumont and 621 miles west of Houston	5,078

Between one-third and one-fourth of the State is less than 500 feet elevation, and perhaps two-fifths is less than 1,000 feet. The Llano Estacado, or Staked Plains, covering about 18,000 square miles, ranges from 3,000 to 4,000 feet in elevation, but appears to be almost level, owing to its very gradual slope.

CLIMATE.

Such wide ranges in latitude, longitude, and elevation give rise to wide variations in temperature and rainfall. The mean annual rainfall for portions of the State bordering on the coast approaches 50 inches, while at El Paso it is little more than 9 inches. The recorded temperatures of the State range from 16° F. below zero, the absolute minimum at Big Spring, to 117° above, the maximum at Amarillo. According to newspaper statements, at the same hour during the winter of 1908, the thermometer stood at 16° below zero at Texline and at 84° above at Brownsville, 800 miles farther south.

The following tables of monthly rainfall, mean, highest, and lowest temperatures, and frost data, are taken from the publications of the U. S. Weather Bureau, and wherever possible the number of years covered by the means is given. The data are given for a few stations only. These are divided into seven groups, corresponding to the arbitrary grouping of data on existing irrigation systems which will follow. The stations were selected so as to give as nearly as possible average values for the rainfall in the sections surrounding them. The values include data for 1907, except for Menardville, which includes nothing after 1903.

MAP OF TEXAS SHOWING STREAMS AVAILABLE FOR IRRIGATION.

Mean monthly and annual rainfall.

Group.	Section.	Length of record.	January.	February.	March.	April.	May.	June.
		Years.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
I.	Orange and Beaumont	25	2.83	3.61	2.90	2.71	3.01	5.02
	Houston	26	4.13	3.50	3.79	3.80	5.14	5.20
	Danevang	12	3.16	3.35	2.95	3.88	3.15	4.35
II.	Beeville	13	1.23	2.16	2.11	2.64	3.18	2.88
	Laureles and Santa Gertrudes ranches	9	.87	2.63	2.08	1.85	2.31	2.73
	Brownsville	37	1.38	1.44	1.33	1.19	2.16	2.25
III.	San Antonio	36	1.46	1.65	1.80	2.76	3.10	2.82
	Eagle Pass—Fort Duncan	32	.75	.85	1.13	1.60	3.13	2.58
IV.	Mount Blanco	22	.66	.88	.58	1.91	2.11	3.04
	Hale Center	14	.29	.53	.48	1.71	2.43	3.24
	Amarillo—Fort Elliott	28	.62	.69	.55	2.11	3.67	3.08
V.	Menardville	15	1.30	1.20	.80	.90	1.70	3.20
VI.	Fort Stockton	30	.40	.43	.65	.47	1.50	1.92
	Fort Davis	33	.54	.50	.39	.54	1.04	1.95
VII.	El Paso [a]	29	.54	.49	.34	.24	.36	.59

Group.	Section.	Length of record.	July.	August.	September.	October.	November.	December.	Annual.
		Years.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
I.	Orange and Beaumont	25	4.70	4.18	2.78	2.92	4.03	3.22	41.91
	Houston	26	3.84	4.05	4.54	3.30	4.05	3.09	48.43
	Danevang	12	5.02	3.66	3.86	4.50	3.98	4.01	45.87
II.	Beeville	13	3.95	1.92	2.79	2.78	2.19	1.73	29.56
	Laureles and Santa Gertrudes ranches	9	2.43	1.87	3.23	2.41	2.44	1.44	26.29
	Brownsville	37	1.87	2.78	5.76	3.27	2.19	1.45	27.07
III.	San Antonio	36	2.49	2.61	3.59	1.99	2.25	1.78	28.30
	Eagle Pass—Fort Duncan	32	1.78	2.58	3.50	1.65	1.12	.93	21.60
IV.	Mount Blanco	22	3.30	2.59	2.24	2.18	1.16	.61	21.26
	Hale Center	14	4.04	2.41	2.80	1.41	1.23	.62	21.19
	Amarillo—Fort Elliott	28	2.38	3.08	2.10	1.99	.88	.84	22.39
V.	Menardville	15	3.00	1.80	2.10	3.30	1.80	1.50	22.60
VI.	Fort Stockton	30	2.07	2.33	3.22	1.43	.75	.72	15.89
	Fort Davis	33	3.47	3.59	2.95	1.34	.60	.58	17.46
VII.	El Paso [a]	29	2.10	1.73	1.41	1.05	.58	.52	9.93

[a] 1879 to 1907, inclusive.

The following tables on mean, highest, and lowest temperatures and frost data contain data for some stations not included in the rainfall table, but are fairly representative of the groups with which they are given.

Highest, lowest, and mean temperatures at stations in Texas.

Group.	Stations.	Length of record.	Highest.		Lowest.		Mean annual, °F.
			°F.	Month.	°F.	Month.	
		Years.					
I	Houston	19	104	July	6	February	68.4
	Galveston	35	98	do	8	do	69.4
	Columbia	18	102	do	5	do	68.8
	Danevang	12	104	do	3	do	69.2
	Victoria	10	104	August	6	do	70.6
II	Beeville	12	107	June	5	do	70.5
	Corpus Christi	19	98	July-August	11	do	70.0
	Brighton	12	102	July	7	do	71.0
	Brownsville	16	102	June, July, September.	12	do	72.7
III	Fort McIntosh	22	111	June	5	do	72.4
	Eagle Pass	19	111	July	7	do	70.7
	Fort Clark	21	109	June	10	do	69.7
	Kerrville	13	105	August	− 2	do	64.0
	Hondo	8	105	June	14	do	
	San Antonio	21	106	July	4	do	67.9
IV	Mount Blanco	20	110	June	−14	do	60.3
	Amarillo—Fort Elliott		108	do	−16	do	55.1
V	Hale Center	13	108	July	− 8	do	60.3
	Menardville	15	108	do	3	March	64.0
VI	Fort Stockton	12	114	June	2	February	62.8
VII	Fort Davis	18	111	do	− 3	do	60.2
	El Paso	33	[a]113	do	− 5	December	62.9

[a] Believed to be too high, as instruments were improperly exposed during first few years of record.

Frost data at stations in Texas.

Group.	Stations.	Length of record.	Average date of first killing frost in autumn.	Average date of last killing frost in spring.	Earliest date of killing frost in autumn.	Latest date of killing frost in spring.
		Years.				
I	Houston		Nov. 24	Feb. 20	Nov. 4	Mar. 26
	Galveston	37	Dec. 26	Feb. 3	Dec. 4	Mar. 1
	Columbia	14	Nov. 25	Feb. 25	Oct. 27	Mar. 24
	Danevang	12	Nov. 23	Feb. 24	Oct. 26	Do.
	Victoria	7	Dec. 11	Feb. 20	Nov. 12	Mar. 20
II	Beeville	13	Dec. 7	Feb. 16	Oct. 27	Mar. 6
	Corpus Christi	21	Dec. 26	Feb. 20	Nov. 30	Mar. 19
	Brighton	14	Dec. 13	Feb. 13	Nov. 12	Feb. 25
	Brownsville		Dec. 18	Feb. 15	Nov. 15	Mar. 5
III	Fort McIntosh	15	Nov. 28	do	Nov. 11	Mar. 3
	Eagle Pass	14	Nov. 21	Feb. 27	Oct. 27	Mar. 22
	Fort Clark		Nov. 20	Feb. 23	Nov. 2	Mar. 20
	Kerrville	13	Nov. 8	Mar. 21	Oct. 24	Apr. 10
	Hondo	7	Nov. 19	Feb. 28	Nov. 12	Mar. 21
	San Antonio	23	Nov. 28	Feb. 24	Nov. 9	Mar. 20
IV	Mount Blanco	16	Oct. 31	Apr. 9	Oct. 18	May 4
	Hale Center	11	Oct. 30	Apr. 2	Oct. 20	Apr. 30
V	El Paso	29	Nov. 11	Mar. 20	Oct. 30	Apr. 22

NATURAL RESOURCES.

In the extreme eastern and southeastern parts of the State there are splendid forests of longleaf and loblolly pine, which are being converted rapidly into building lumber. Farther west, but still in the eastern part, are large bodies of oak, ash, and other hardwoods, which are being used for manufacturing furniture. Fine live-oak trees are found in portions of the country along the coast in the eastern part of the State, but farther south, where the rainfall is less, all other timber

growths are replaced by chaparral, mesquite, and similar trees. The western part of the State, except the tops of the higher mountains, is generally treeless, but for mesquite and chaparral. The mountain tops are covered with pine and hardwoods. In the central part of the State fine groves of pecan, hackberry, cottonwood, and similar trees are frequently found along the water courses. The gathering of pecans has become quite an industry in the west-central part of the State, and the trees are being cultivated and improved systematically at Brownwood and other places. The Staked Plains are devoid of natural timber, but in many places excellent trees can be grown even without irrigation, although in the more arid regions it is necessary. Practically the entire northeastern part of the State is a Tertiary formation and is crossed by several forest strips of post oak, intermingled with many other kinds of trees. These strips are usually about 10 miles wide and extend 100 miles or more in a northeasterly and southwesterly direction. The timber is used for fuel principally.

Large portions of the Tertiary formation in the eastern and east-central parts of the State are underlaid with vast deposits of lignite. In one case a deposit with a thickness of at least 9 feet was traced for a distance of practically 3 miles. It was not possible to work the deposit, as it was located 9 or 10 miles from a railroad and the railroad company could not be induced to construct a branch. The lignite in the vicinity of Rockdale, Calvert, Laredo, Eagle Pass, and a few other points near railroads is mined and shipped to many places to use for power generation. A project to construct an enormous producer-gas plant near Rockdale to generate electricity to be transmitted to neighboring towns and even to Dallas, Waco, and Houston, has been mentioned. Bituminous coal is mined near Thurber and El Paso and deposits are known to exist at other points. Crude oil and natural gas are found at a number of points in the State and are extensively used for power generation, being cheaper than coal for that purpose. Large deposits of workable iron are found at Rusk and others are known to exist at many other places.

The principal development that has been made in the State outside of the cattle industry is agricultural. Manufacturing industries of many kinds are beginning to spring up. There are more than a dozen cotton mills in operation, but this should be only the beginning. The State operates an iron furnace with convict labor at Rusk. Smelters for reducing gold, silver, copper, and other ores are operated in the vicinity of El Paso. Plants for manufacturing cast-iron articles and for the fabrication of structural steel and iron are operated at Beaumont, Houston, Dallas, and other places. As yet there are no steel-rolling mills in the State.

TRANSPORTATION.

Railroad development in Texas has been greatest in the eastern and central parts of the State, and fully half the mileage lies in the eastern third of the State. The Texas Railroad Commission, in its report for 1907, placed the total mileage of steam roads at 12,575.56. R. A. Thompson, engineer for the commission, estimates that 341.18 miles additional had been built to June 30, 1908. Besides the steam roads, there were about 112 miles of electric interurban roads and some 300 miles of logging or private roads.

While Texas ranks first among the States in railroad mileage, the traffic of the State by inland waterways is very limited. Operations are in progress having in view the improvement of the Trinity and Brazos rivers and Buffalo Bayou and the construction of a coastal canal. Galveston, in point of export shipments, is probably the principal port of the Gulf and South Atlantic States.

TAXATION.

The total valuation of all property assessed for the year ending August 31, 1907, was $1,636,297,115, according to the annual report of the comptroller of public accounts. This was a net increase of $414,137,246 over the previous year. The total taxes assessed for the year 1907, including State, poll, and county, were $7,320,227.64.

EDUCATION.

Texas has a larger permanent endowment for public schools than any other State, but owing to the small amount supplied by local taxation the expenditure per pupil in attendance—$12.76 in 1906—was just half the average for the entire United States. This is being increased, however, as many communities are forming independent school districts.

Texas has a large number of denominational colleges and universities, as well as a state university, the main branch of which is at Austin and the medical department at Galveston. The Agricultural and Mechanical (land-grant) College, receiving aid from the United States Government under the Morrill acts, is located at College Station, and offers inexpensive education in agricultural and engineering lines. State normal schools are maintained at Huntsville, San Marcos, and Denton, and the State Normal and Industrial College for Girls is also located at Denton. There is a state normal and industrial college for negroes at Prairie View, in Waller County. This college shares with the Agricultural and Mechanical College in federal aid under the Morrill acts. An agricultural experiment station, supported mainly by federal funds under the Hatch and Adams acts is organized

as a department of the Agricultural and Mechanical College, and is located at College Station. Substations supported by state funds are maintained at Beeville, Troup, and Chillicothe. The U. S. Department of Agriculture maintains experimental farms at Brownsville and San Antonio, and has conducted special experiments in different parts of the State.

CROPS.

The following statistics regarding some of the principal crops of the State have been compiled from the Yearbook of the U. S. Department of Agriculture for the year 1907:

Crop of 1907.

Crop.	Area.	Production.	Value.	Yield per acre.	Value per acre.
	Acres.				
Corn	7,409,000	155,589,000 bushels	$93,353,000	21 bushels	$12.60
Wheat	380,000	2,812,000 bushels	2,784,000	7.40 bushels	7.33
Oats	500,000	9,500,000 bushels	5,700,000	19 bushels	11.40
Barley	4,000	68,000 bushels	50,000	17 bushels	12.50
Rye	4,500	45,000 bushels	45,000	10 bushels	10.00
Potatoes	33,000	2,409,000 bushels	2,529,000	73 bushels	76.64
Hay	380,000	494,000 tons	5,310,000	1.30 tons	13.97
Cotton	9,156,000	2,300,179 bales			
Tobacco	500	350,000 pounds	105,000	700 pounds	210.00
Rice	284,000	9,088,000 bushels	7,725,000	32 bushels	27.20

Texas was credited with the production of 12,000 long tons of cane sugar, but the acreage and value were not given. The value of the cotton crop was not given by States, but from the total for the whole of continental United States, the proportion of Texas was worth something more than $125,000,000. For 1907 the cotton production was low; during 1906, with only 8,894,000 acres, the production amounted to 4,174,206 bales of 500 pounds each, and in 1908 the crop was 3,814,485 bales, the acreage being 9,316,000.

Details for sugar-cane acreage, sorghum, cotton-seed oil products, turpentine, fruit, garden truck, etc., were not obtainable.

There were 1,278,000 head of horses, worth $83,070,000; 637,000 mules, worth $57,967,000; 1,072,000 milch cows, worth $27,872,000; 7,825,000 other cattle, worth $93,900,000; 1,300,000 sheep, producing 8,450,000 pounds of washed and unwashed wool; and 3,147,000 swine, worth $16,522,000.

For the year 1908 it is probable that the quantities and values of many of the above products have been materially increased, except cotton and cotton-seed products.

WATER RESOURCES.

The water resources of Texas have only begun to be developed. There are millions of acres of arable land within the State susceptible of cultivation under irrigation to a degree limited only by the amount

of water available. Rice irrigation has been developed along the coast, but in addition to large areas still available in that section there are vast bodies of rich bottom land along the lower reaches of the principal rivers which can be irrigated by pumping for the cultivation of rice, sugar cane, alfalfa, and other crops. Toward the sources of such streams as the Brazos, the Colorado, and the Wichita rivers, where the rainfall is of periodic occurrence, and the land normally arid or semiarid, it is possible to construct impounding reservoirs to conserve the run-off. There are areas in eastern and central Texas also where the rainfall is more uniformly distributed and the amount is ordinarily sufficient to raise good crops on which irrigation could be made to pay as an adjunct to the rainfall, particularly in the cultivation of fruits and vegetables.

In the western portion of the State large areas have been regarded as practically desert. This land is very fertile when touched by water, and it would seem possible to construct reservoirs to conserve the run-off from the steep mountain sides during heavy rains which are of such short duration that the greater part of the water runs off. Irrigation in the vicinity of El Paso and Del Rio, and in the Laguna district of Coahuila, Mexico, shows conclusively that all these lands need to convert them from desert wastes into fertile farms is water. Attempts to cultivate crops without irrigation in these regions can result only in failure, as has been demonstrated along the line of the Southern Pacific Railroad beyond Del Rio.

RIVER SYSTEMS.

With the exception of Wichita River, Pease River, Prairie Dog Fork, and the direct drainage along the eastern portion of the northern border of the State, the water from which area reaches the Gulf of Mexico by way of the Red and the Mississippi rivers, the river systems in Texas flow southeast and empty directly into the Gulf of Mexico. Reckoning from east to west the principal systems of this group are the Sabine, Neches, Trinity, San Jacinto, Brazos, Colorado, Guadalupe, San Antonio, Nueces, Pecos, and Rio Grande rivers. Of these the Trinity, Brazos, and Colorado are the principal ones which lie almost wholly within the State and drain vast areas of land.

SABINE RIVER.

The Sabine River, which forms the boundary between Louisiana and Texas for nearly 200 miles, heads in Hunt and Collin counties and flows southeasterly for 150 or 200 miles to the state line, then turns south and finally empties into Sabine Lake. At the lower end of the channel which forms the outlet to this lake is situated Port Arthur, a harbor for vessels of light draft. The river is navigable for small boats for a considerable distance above its mouth.

The drainage area of the Sabine River above Orange, in Texas, is about 7,500 square miles. On the lower portions of the stream are many rice-irrigation systems. Higher up on the watershed are several small power plants which utilize heads ranging from 5 to 25 feet. On account of the fairly uniform distribution of rainfall and the vegetation covering the watershed, the ordinary flow of this and other east Texas streams is much more uniform than that of the streams farther west.

Below are the results of discharge measurements at the gaging station established near Longview by Professor Taylor, of the Hydrographic Division of the U. S. Geological Survey.[a]

Estimated discharge of Sabine River near Longview, Tex.

[Drainage area, 2,900 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1904	6,544	36	811	585,600
1905	19,480	122	4,290	3,138,000
1906	13,200	74	2,270	1,630,000

For the year 1904 the minimum discharges for the months of August, September, October, November, and December were 44, 44, 36, 53, and 44 cubic feet per second, respectively, and the corresponding maximum discharges for the same months were 580, 426, 63, 109, and 869 cubic feet per second. The greatest discharge occurred during April, when the maximum was 6,544 cubic feet per second, while the minimum was 620 cubic feet per second.

For 1905 the minimum discharges for the months of August, September, October, November, and December were 162, 135, 122, 483, and 660 cubic feet per second, respectively, while the maximum discharges for the same times were 7,316, 326, 1,461, 2,907, and 17,360 cubic feet per second, respectively. The maximum for the year occurred in May, and was 19,480 cubic feet per second, while the minimum for that month was 9,735 cubic feet.

NECHES RIVER.

The Neches River heads in Van Zandt County, flows southeasterly through the heavily wooded portion of east Texas, and empties into Sabine Lake 18 or 20 miles above Port Arthur. The drainage area above Evadale, at which point the U. S. Geological Survey maintains a gaging station, is 8,200 square miles. For the last half of 1904 the minimum discharge of 202 cubic feet per second occurred in November and the maximum of 7,590 cubic feet occurred in December. The total discharge for the six months was 239,200 acre-feet.[b]

[a] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 99 and 174.

[b] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 99, 174, and 210.

Estimated discharge of the Neches River at Evadale, Tex.

[Drainage area, 8,200 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1905	18,300	484	7,059	5,114,000
1906	12,300	560	3,920	2,830,000

The minimum for the year 1904 (484 cubic feet per second) occurred in October and the maximum (18,300 cubic feet per second) occurred in May, with March, April, June, and July running high also.

The principal tributary of the Neches is Angelina River, which unites with the Neches a few miles below Rockland. There are a number of small water-power plants on the Neches and its tributaries, utilizing water under heads varying from 4 to 32 feet. In Jefferson County, particularly, the water from this stream is extensively utilized in rice irrigation. The total length of the Neches River is approximately 300 miles.

TRINITY RIVER.

The Trinity heads in Montgomery, Wise, Jack, and other counties which lie close to the Red River, on the northern boundary of the State, and flows southeasterly for 600 or 700 miles to its outlet, in Galveston Bay. Its length above Dallas does not greatly exceed 150 miles, and ordinarily the flow at that point is quite low, sometimes practically ceasing. During the spring of 1908 torrential rains on the watershed above Dallas caused severe damage by floods in the lower portion of the city.

There are a few small power plants in the watershed of the Trinity, which utilize heads ranging from 8 to 22 feet, but the power developed is low. On the lower portions of the stream rice irrigation is practiced, and a much larger use of the water for this purpose and for the irrigation of other crops, such as sugar cane, alfalfa, etc., is possible by pumping. Some years ago an examination was made of a site for a reservoir near Shepherd, where it is possible to utilize the water from one of the small tributaries of the river. Impounding reservoirs may be located in many places on the upper reaches of the stream.

A system of locks and dams is now being installed by the United States Government with a view to making the stream navigable for small boats for a portion of the year from the mouth of the stream to Dallas. While this is easily possible for the lower portions of the river, the small discharge on the upper portion will make it difficult during the season of small flow. For several years a gaging station was maintained at Dallas by the U. S. Geological Survey, but was

finally abandoned because of the small discharge. Beginning with the year 1903, the Survey has maintained a gaging station at Riverside, Tex., the summary of results of measurements, so far as available, being given below:

Estimated discharge of Trinity River at Riverside, Tex.[a]

[Drainage area, 16,000 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1903	27,270	225	6,897	4,983,895
1904	17,610	160	2,936	2,124,000
1905	38,500	360	10,770	7,835,000
1906	22,800	386	7,200	5,200,000

[a] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 99, 174, and 210.

BRAZOS RIVER.

The Brazos is the longest river in Texas and discharges the most water. Its total drainage area is equal to the area of the State of Pennsylvania. Its headwaters originate in the Llano Estacado (Staked Plains), with possibly some intermittent drainage from eastern New Mexico. The general trend is southeasterly. Its principal branches are Double Mountain and South Forks, which unite in Stonewall County; Clear Fork, which joins the main channel in Young County; Little River, the mouth of which is in Milam County; and the Navasota River, which joins the main stream in Grimes County. There are a number of smaller tributaries, such as the Little Brazos and the Yegua, which contribute considerable quantities of water after heavy rainfalls.

The U. S. Geological Survey maintains gaging stations at Waco and Richmond, and for three years (1900–1902) measurements were carried on for this Office at Jones Bridge, Brazos County, and at Richmond during the summers of 1901 and 1902. The results of these measurements, as far as they are now attainable, are given in the table below:

Estimated discharge of Brazos River at Waco, Tex.[a]

[Drainage area, 30,800 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1899	77,076	26	3,025	2,191,255
1900	98,832	315	5,755	4,151,940
1901	38,017	61	836	605,241
1902	74,600	20	2,694	1,968,668
1903	65,000	90	1,360	1,434,842
1904	17,180	72	1,180	858,500
1905	85,500	184	3,775	2,754,000
1906	40,900	284	2,350	1,700,000

[a] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 75, 84, 99, 132, 174, and 210.

Discharge of Brazos River at Jones Bridge, Tex.[a]

[Drainage area, 37,400 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1900	135,000	1,020	12,021	8,706,796
1901	19,392	246	1,349	976,602
1902	65,934	213	4,645	3,362,991

[a] U. S. Dept. Agr., Office Expt. Stas. Buls. 104, 119, 133.

A gaging station was established at Richmond, Tex., by the U. S. Geological Survey in December, 1902, and for this station the following results are available:

Estimated discharge of the Brazos River at Richmond, Tex.[a]

[Drainage area, 44,000 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1903	66,550	945	8,601	6,213,080
1904	47,590	820	3,377	2,461,000
1905	65,590	1,160	12,490	9,098,000
1906[b]	37,300	1,290	.....	1,660,000

[a] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 99, 132, 174, and 210.
[b] January to June, inclusive.

During the irrigation seasons of 1901 and 1902 a gaging station was maintained for this Office at Richmond, and the following mean daily discharges were obtained for 1901: July, 1,080; August, 966; September, 1,304; and October, 1,104 cubic feet per second. The minimum discharge found in 1901 was 710 cubic feet per second. For the year 1902 the mean daily discharges were: June, 3,640; July, 6,787; August, 25,720; and September, 3,660 cubic feet per second.

The foregoing results show wide variations at all stations for various years, the run-off depending not only upon the amount of rainfall, but upon its distribution. The years 1901 and 1904 were years of small rainfall and the run-off shows the results of this very plainly. It will be noticed that the discharges at Richmond are three or four times as great as the corresponding discharges at Waco. This is due to the run-off contributed by tributary streams which enter below Waco.

At certain stages the Brazos River carries large quantities of sediment, the bulk of which appears from its red color to be derived from the Permian formation on the upper portions of the watershed.

Summary of silt measurements, Brazos River, Tex.[a]

[Collections made at Jones Bridge.]

Time.	Total discharge.	Silt—one week's settlement.		Silt—one year's settlement.	
	Acre-feet.	*Acre-feet.*	*Per cent.*	*Acre-feet.*	*Per cent.*
August 1 to December 31, 1899	1,165,300	10,090	0.866	7,567	0.649
January 1 to December 31, 1900	8,806,986	115,782	1.315	86,837	.986
January 1 to December 31, 1901	976,602	12,838	1.262	9,246	.947
January 1 to December 31, 1902	3,362,991	40,190	1.195	30,142	.896
Total for 41 months	14,311,879	178,900	1.246	133,792	.935

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 133, p. 205.

During 1902 the collections were made at much shorter intervals than for the time preceding, but the results are only a little smaller than for the entire period. Probably a mean value of 1.2 per cent by volume for one week's settlement and 0.9 per cent for one year's settlement would be not far wrong as an estimate of general conditions. The percentages of silt were determined volumetrically, and are much larger than similar determinations based on weights where the weight of a given volume of the sediment has been assumed.

In the projection of storage reservoirs on this stream the effect of such large quantities of sediment should be carefully considered. From the vicinity of Waco to its mouth, a distance of perhaps 300 miles, the Brazos River bottom-lands are subject to overflow, and in the slack waters heavy deposits of silt are often formed. The overflows of 1908 have caused several projects for building levees along portions of the stream to be talked of, but nothing definite has been accomplished.

It does not seem probable that extensive storage reservoirs will be attempted on the lower stretches of this river, because of the generally unstable character of the bottom and banks of the river, although it is possible to construct dams on stable foundations at a few points, such as the rock falls below Marlin. Any such reservoir would have its storage capacity reduced materially in time by the deposit of silt, as was the case with the Austin dam across the Colorado River. On the upper portions of the watershed on the various tributaries, such as Clear and Salt forks, impounding reservoirs are possible and something of the kind has been projected. There are several small wood and brush dams also which have been built for power development on the Clear Fork, Leon, Bosque, Lampasas, Salado, San Gabriel, and Navasota rivers, all tributaries of the Brazos, but as yet the power developed is low, probably not exceeding 50 horsepower for any one plant.[a]

[a] U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 105.

A system of locks and dams is being constructed on this river with a view to making it navigable for small craft from Waco to its mouth during certain seasons of the year.

In Fort Bend and Brazoria counties considerable water is now being pumped from the Brazos for rice irrigation, but opportunities still exist for large development along this and other lines in these counties.

WICHITA RIVER.

The Wichita heads in King and Cottle counties and has a general eastward trend for its whole length of about 150 miles. It empties into Red River about 20 or 25 miles northeast of Wichita Falls. In Knox and Baylor counties the Wichita and the Salt Fork of the Brazos approach within a few miles of each other, and it was proposed some years ago that a dam be constructed across the latter river to divert a large portion of its waters through a canal on to the watershed of the Wichita, but this plan has not been carried out. A gaging station was established for this Office at Wichita Falls in 1899, and the results of all consecutive discharge measurements are given below:

Discharge of Wichita River at Wichita Falls, Tex.[a]

[Drainage area, 3,050 square miles.]

Time.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
February 10 to December 31, 1900	16,400	51	1,307	842,453
January 1 to December 31, 1901	72,620	4	410	297,883
January 1 to February 15, 1902	6	4	4.8	436

[a] U. S. Dept. Agr., Office Expt. Stas. Buls. 104 and 119.

During 1900 the maximum discharge occurred during the latter part of July, while in 1901 it occurred during the latter part of May. The minimum in 1900 occurred in December, and in the same month in 1901. The total discharge during the latter year, however, was only a little more than one-third that of the preceding year.

The foregoing measurements were made with a view of ascertaining whether or not there was sufficient discharge to properly maintain a projected irrigation system on this river, the storage reservoir for which was to have been located perhaps 40 miles above Wichita Falls, and was designed to impound about 200,000 acre-feet.

Measurements of the quantity of silt carried by the waters of this stream were also made. For the period from February 10 to December 31, 1900, 10,172 acre-feet of silt was carried down, as determined volumetrically after one week's settlement. This corresponds to a percentage of 1.207 for one week, or approximately 0.906 per cent after one year's settlement. For the year 1901 about

4,640 acre-feet or 1.557 per cent at one week's settlement was obtained, which equals 1.168 per cent, approximately, for one year's settlement. The foregoing results clearly indicate that the effect of silt upon the storage capacity of a reservoir situated on this stream should not be left out of consideration.

The soil along the Wichita River is very rich and produces excellent crops during favorable seasons. Irrigation as a supplement to the normal rainfall of about 25 inches should render it as productive as could be desired. During the spring of 1901 a reservoir of about 13,000 acre-feet capacity, and covering about 1,500 acres, was constructed on Holliday Creek, about 4 miles south of Wichita Falls, but the results of this experiment are not available.

COLORADO RIVER.

The Colorado River rises in Gaines and Colorado counties, with possibly some contributary drainage area in southeastern New Mexico. Its drainage area is not very much smaller than that of the Brazos, but owing to smaller general rainfall on much of its watershed the total run-off is considerably less. The following tables give the results of discharge measurements on this stream, as far as they are available:

Estimated discharge of Colorado River at Austin and Columbus, Tex.[a]

AUSTIN.

[Drainage area, 37,000 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1896	14,100	180	1,460	
1897	11,000	200	1,200	
1898	29,000	210	1,880	
1899	103,400	180	1,170	
1900	123,000	410	3,115	
1901	40,912	175	1,994	1,350,557
1902	31,250	180	2,224	1,619,108
1903	33,070	320	1,300	1,550,434
1904	46,140	200	1,595	1,154,000
1905	51,190	175	1,918	1,360,000
1906	70,300	175	3,060	2,230,000

COLUMBUS.

[Drainage area, 40,000 square miles.]

1904	28,900	390	2,225	1,517,000
1905	37,900	680	3,358	2,444,000
1906	38,000	880	2,730	1,980,000

[a] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 84, 99, 105, 132, 174, and 210.

During the rice-irrigation seasons of 1901 and 1902 a gaging station was maintained at Wharton for this Office, where the mean daily discharges for the last half of June and the months of July, August,

September, and October were found to be in 1901, 1,018, 1,835, 816, 1,818, and 810 cubic feet per second, respectively. For the months of June, July, August, and September, 1902, the mean daily discharges were 1,369, 3,921, 7,531, and 3,070 cubic feet per second, respectively.[a]

The minimum discharge of 459 cubic feet per second in 1901 occurred on July 9, and during the first fifteen days of that month the mean daily discharge averaged only about 550 cubic feet per second. During the latter half of August it was not very much greater. On June 28, 1902, the minimum discharge occurred, amounting to only 405 cubic feet per second, but the mean for the month was 1,368 cubic feet per second. The maximum for this season occurred on August 3, and amounted to 41,563 cubic feet per second. Altogether, much more water passed down during 1902 than during 1901.

Rice irrigation along the Colorado has been highly developed both above and below Wharton, and judging by the amount of water pumped below, it would seem probable that the discharge lower down is increased by seepage from the water-bearing strata of the locality.

Below Austin the channel of the Colorado lies in alluvial bottom-lands, but above it is largely in limestone formations. Hence above Austin there are many sites where masonry dams for irrigation and water-power development could be constructed. The most favorable site is probably at Marble Falls, 40 miles above Austin, where there is a natural fall of 12 feet and in a distance of 1.25 miles a total fall of 47 feet.[b] Nearly half this fall could be utilized at comparatively little expense, and all of it without difficulty. An abundance of excellent granite may be had at Granite Mountain, 2 miles distant, on the line of the Houston and Texas Central.

The natural fall is now being utilized in pumping water for Marble Falls, and the minimum recorded flow is 160 cubic feet per second. The flow of the river is to be utilized by a manufacturing company, which is constructing a dam 18 feet high on the crest of the falls at a cost of about $300,000 and by which the engineer estimates that 1,000 to 1,200 horsepower will be developed under 30-foot head.

Many excellent sites for dams exist still higher up the river and on its tributaries, and a few have been built, such as those at Kingsland and Bluffton. Austin dam, of which the construction, power house, water mains, street lighting, etc., cost $1,600,000, is situated just above Austin at the mouth of the canyon-like channel through the limestone formation. This dam was completed in 1891 and was broken by a severe flood in April, 1900. At Columbus, 75 or 100

[a] U. S. Dept. Agr., Office Expt. Stas. Buls. Nos. 119 and 133.

[b] U. S. Geol. Survey, Water-Supply and Irrig. Papers No. 105.

miles above the mouth of the river, a power plant has been suggested and surveys made for same, but the alluvial banks of the river present difficulties here, as is the case for the lower reaches of all Texas streams.

The Pedernales, Llano, and San Saba rivers, Pecan Bayou, and the Concho River are the principal tributaries, of which the Llano and the Concho carry most of the water. Numerous small dams have been built on these streams for power and irrigation purposes, of which the most important now in operation is the stone and concrete dam at San Angelo, Tom Green County.

There are several small dams on the Concho which are utilized in diverting water for irrigation and some for generating a small amount of power; also on the tributaries of these streams and the San Saba, the latter of which has a reliable, though small flow. There are excellent opportunities for constructing impounding reservoirs. The Llano River affords excellent sites for dams and reservoirs, and there are a number of small power plants along its source, as at Junction and Llano. At the latter place waterworks, an electric-light plant, and power for commercial purposes are operated by water power developed by means of a small dam across the stream.

GUADALUPE RIVER.

The Guadalupe River heads in Kerr County, 75 or 100 miles northwest of San Antonio, and empties into San Antonio Bay. Its total length is approximately 300 miles. Its principal tributaries are the San Marcos and Comal rivers. The latter is quite short, but furnishes considerable water derived from springs which issue from fissures in the rocks at the edge of the Edwards Plateau. The San Marcos also has its origin in similar springs near the town of the same name, about 50 miles east of San Antonio.

While the discharge of the Guadalupe in the vicinity of New Braunfels (32 miles east of San Antonio) has been found to be as small as 13 cubic feet per second the lowest recorded discharge of the Comal at New Braunfels is 310 cubic feet per second, while that of the San Marcos at the town of the same name was 89 cubic feet per second.[a]

The United States Geological Survey maintains a gaging station on the Guadalupe, near Cuero, from the records of which the following results are taken.[b]

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[a] U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 105.

[b] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 99, 132, 174, and 210.

Estimated discharge of the Guadalupe River near Cuero, Tex.

[Drainage area, 5,100 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1903	71,300	755	2,487	1,798,056
1904	6,886	465	819	595,300
1905	10,580	545	1,318	935,700
1906	4,650	370	643	464,000

While the drainage area above Cuero is only 5,110 square miles, the Guadalupe is perhaps the best power stream in the State. This is due to the volume of water supplied by the springs which form the Comal and San Marcos rivers. In the vicinity of New Braunfels the available water power has been quite freely used, several hundred horsepower being developed there for electric lighting and manufacturing purposes. Above New Braunfels are several small power plants, and there are similar ones below. In the neighborhood of Seguin are several plants, which together are capable of developing several hundred horsepower, as is the case for plants at Gonzales and in the vicinity of Cuero. On the San Marcos River, at and below the town, are more than a dozen small power plants, which together develop several hundred horsepower under low heads. One at San Marcos furnishes water to the town, another yields power for electric lights, while a third is utilized in manufacturing ice.

By increasing the heads and developing new sites the water power of the Guadalupe and its tributaries may be greatly increased, and by reason of the comparative proximity of San Antonio, Austin, and a number of small towns it would seem that at some future time the development of power for electric transmission would prove an attractive proposition.

SAN ANTONIO RIVER.

The San Antonio River proper rises 3 miles north of the center of the city of San Antonio and is fed almost entirely by springs, though it has considerable contributary drainage area on the northwest by way of the Medina River and on the east by Cibolo Creek, the former joining the main stream 12 or 15 miles below the city of San Antonio, while the latter enters in Karnes County, about 50 miles below the city. In San Antonio and vicinity are many artesian wells, which evidently derive water from the same stratum which supplies the springs, for these wells have materially affected the discharge of the springs at times, and both show a marked diminution of flow during prolonged dry spells. Some of the artesian wells are utilized for the water supply for the city waterworks, while others in the outlying districts furnish water for irrigation.

There are several power plants in San Antonio, but the variability of flow of late years has made it necessary to install auxiliary steam plants at some of these. Prof. T. U. Taylor found the discharge of the river as low as 9 cubic feet per second at the hot wells below San Antonio in March, 1898, and as high as 125 cubic feet per second at the same point in September, 1900, since which time measurements have shown discharges varying between 41 and 117 cubic feet per second, the latter measurement having been made in September, 1905.[a] Evidently the heavy rainfall of 1899 and 1900 was responsible for the increase.

From the upper power house in San Antonio to a point a short distance below the city the total fall is in excess of 100 feet, and it would seem possible to further develop the production of power. It is possible also that the use of water for irrigation in the vicinity may be extended, though some of these systems are reported to command as much as 500 acres at the present time. From the city of San Antonio to the junction of the San Antonio and Guadalupe rivers, a few miles above the point where they enter San Antonio Bay, the distance is perhaps 115 miles on an air line.

NUECES RIVER.

The drainage of the Nueces River begins in Edward County, and the stream has a general southeasterly trend for nearly 300 miles to its outlet in Corpus Christi Bay. Its principal tributary is the Frio River, which joins the Nueces near the town of Oakville. The upper portion of this stream is fed by springs and there is a nearly constant flow which is partly used for irrigation. For a distance of a few miles near the Southern Pacific Railway crossing west of Uvalde the flow disappears in the gravel bottom, but reappears farther down. Springs add to the discharge of this river on the lower portion, increasing it materially.

Near Cotulla there are several irrigation plants which pump against an average head of 30 feet and water several hundred acres, planted chiefly to Bermuda onions. One of these plants operates successfully against a head of 45 feet.

DEVILS RIVER.

Devils River, less than 100 miles long, has a watershed which begins in Sutton and Crockett counties, and it empties into the Rio Grande 12 or 15 miles northwest of Del Rio. Its real source, however, is in Pecan Springs, about 50 miles above its mouth. The following results of discharge and gage-height measurements are available.

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[a] U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 174.

Estimated discharge of Devils River at Devils River, Tex.[a]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1901	840	480	627	453,421
1902	5,380	380	491	355,219
1903	10,400	380	587	415,137
1904	1,580	410	520	377,652
1905	6,470	425	667	482,977
1906	30,000	350	837	609,797

[a] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 174 and 210.

The foregoing summary is the result of measurements made by the International (Water) Boundary Commission.

The water in Devils River is clear and sparkling and could be utilized for irrigation in the vicinity of Del Rio. Just east of Del Rio, San Felipe Creek rises from springs and furnishes water for extensive irrigation and for power purposes. From a number of discharge measurements made on this stream by Professor Taylor for the years 1895 to 1905 the minimum discharge was 99 cubic feet per second in 1895. The next smallest was 103 cubic feet per second in 1905. The creek empties directly into the Rio Grande a few miles below Del Rio.

PECOS RIVER.

This river rises far up in the mountains of New Mexico, but from the point where it enters Texas on the boundary line between Loving and Reeves counties to the point where it empties into the Rio Grande, about 40 miles northwest of Del Rio, its length is upward of 250 miles. Large irrigation systems in the vicinity of Barstow and Grand Falls successfully utilize the water from this river, notwithstanding it is highly impregnated with alkali. Some little use of the water for power purposes has also been made at Barstow and Grand Falls, and this use may be extended.

Nearly 100 miles above its mouth the river enters a gradually deepening canyon, and at Viaduct, the Southern Pacific Railway crossing, the top of the rail is 321 feet above low-water level. The rocky walls and bottom of the canyon afford excellent opportunities for the construction of dams for storage reservoirs, but so far the water has not been utilized here, either for power generation or for irrigation.

The following table shows the summary of results of measurements on the Pecos River near Moorehead, close to the high bridge of the Southern Pacific at Viaduct.

Estimated discharge of the Pecos River at Moorehead, Tex.[a]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
1901	9,200	160	633	457,249
1902	11,100	210	578	419,107
1903	2,140	170	408	294,318
1904	17,500	110	861	623,922
1905	14,570	470	1,246	904,880
1906	35,570	415	920	669,094

[a] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 75, 84, 99, 132, 174, and 210.

RIO GRANDE.

Lying west of the Pecos is an area of approximately 32,000 square miles in Texas which is practically unwatered, except for a few creeks leading into the Pecos on the east and similar ones into the Rio Grande on the west. The annual rainfall in this trans-Pecos region is small, but the rate of precipitation is frequently great, which, combined with the steep slopes of the mountain sides, converts the otherwise dry arroyos into raging torrents at times. The springs near Toyah furnish water for the irrigation of hundreds of acres, and in the vicinity of El Paso lands on both sides of the river are irrigated by water diverted from the Rio Grande when there is water flowing in the channel. Irrigation systems higher up have absorbed most of the ordinary flow of this river, and as a consequence irrigation is practiced on a much smaller scale than formerly. In Presidio and Brewster counties irrigation from springs is practiced to some extent.

Near Eagle Pass irrigation is practiced to a considerable extent, water being pumped from the Rio Grande for this purpose and utilized in growing onions and garden truck. Also near Laredo large areas are planted to onions, etc., and watered by pumping from the Rio Grande.

In the vicinity of Hidalgo there are large areas of irrigated alfalfa, sugar cane, sorghum, corn, onions, etc., for which the Rio Grande furnishes the necessary water. From Hidalgo on down the river extensive irrigation plants have been constructed during the last few years or are now in process of building, where sugar cane, alfalfa, truck crops, melons, etc., are extensively cultivated and will soon be grown on a much larger scale.

Omitting the smaller sinuosities of the stream, which are very pronounced for the entire length of the river, especially in the alluvial bottoms, the Rio Grande forms the boundary between Mexico and Texas for about 900 miles. For a large part of this distance it flows through picturesque rock canyons.

Below are given results for a few points on the Rio Grande, the discharges having been determined by the International (Water) Boundary Commission:

Estimated discharge of the Rio Grande near El Paso, below Presidio, and near Eagle Pass, Tex.[a]

[Drainage area, 30,000 square miles.]

Year.	Maximum.	Minimum.	Mean.	Total.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*
NEAR EL PASO.				
1901	3,980	0	499	363,968
1902	2,140	0	70	50,768
1903	18,070	0	1,429	1,032,844
1904	17,100	0	643	472,781
1905	23,680	15	2,782	2,011,794
1906	8,700	10	1,533	1,113,968
BELOW PRESIDIO.				
1901	5,690	20	778	564,732
1902	45,000	10	2,109	1,532,420
1903	8,960	105	1,441	1,043,563
1904	149,200	5	3,573	2,579,703
1905	27,170	720	5,380	3,905,411
1906	37,400	670	5,141	3,734,164
NEAR EAGLE PASS.				
1901	21,460	1,600	3,176	2,298,763
1902	32,000	1,260	3,831	2,778,487
1903	47,400	1,640	4,010	2,904,179
1904	172,300	1,250	7,381	5,336,270
1905	238,300	3,130	11,164	8,102,400
1906	178,650	2,010	10,490	7,634,122

[a] U. S. Geol. Survey, Water-Supply and Irrig. Papers Nos. 75, 84, 99, 132, and 174.

In addition to the above points, at which consecutive measurements have been made by the International (Water) Boundary Commission, similar records have been kept for a number of other points on the river, the results for which and also detailed reports for the points named may be found in the Water-Supply and Irrigation Papers of the U. S. Geological Survey. It will be noticed that at El Paso the river is frequently dry and that the discharge increases materially farther down the river, due to the entrance of tributary streams.

SPRINGS AND WELLS.

In addition to springs, such as Toyah, which are already being used for irrigation, there are a number of others in the mountainous portions of Texas which may be developed for the purpose. Artesian wells at Waco, San Antonio, Kingsville, Carrizo Springs, and other places are now used for city water supplies and some use is made of them also for irrigation. There are many small flowing wells scattered through the Brazos bottoms, but these are used mainly for

domestic purposes and for stock water. In the coast country, at Katy, El Campo, Edna, Victoria, Beeville, and elsewhere, shallow wells furnish large quantities of water for rice irrigation, and it is possible that similar development may be made in localities other than those where this is now known to be possible. This source of supply is capable of further development, but the supply is probably not inexhaustible, as many seem to believe.

LANDS.

Texas has a land area of 262,398 square miles, or nearly 167,936,000 acres. There is no definite data showing what proportion of this can be cultivated, but it would be a very conservative estimate to put it at one-half the total, or about 85,000,000 acres. At present less than one-third of this half is cultivated, and a large proportion of this third can be materially increased in productiveness by the use of more intensive methods, the use of fertilizers, and the aid of irrigation. Perhaps 75 per cent of that portion of the State lying below the 1,000-foot contour can be brought under cultivation as far as the character of the land is concerned, but some of this area will require artificial application of water before success can be expected. The roughest portion of the State lies in the trans-Pecos region, much of which is unfit for grazing, though some of it is mineral bearing.

Of the crops grown, cotton leads, with an acreage of 10,000,000 acres or more; corn comes next, with something like 7,000,000 acres; and mixed crops make up a large proportion of the balance. Rice covers nearly 250,000 acres, and the area under orchards, especially peaches in eastern Texas, is constantly increasing.

There are no forest reserves in the State and no reclamation work has been done so far by the Government, though the benefits of the Reclamation Act were extended to Texas by act of Congress of June 17, 1902, and the provisions of this act were formally accepted by the twenty-ninth legislature of the State, during April, 1905. There is a movement on foot to construct a canal which will serve 45,000 acres in the Texas portion of the Rio Grande Valley from the Rio Grande project of the U. S. Reclamation Service.

The last printed report of Mr. John J. Terrell, commissioner of the general land office of the State of Texas, covering the two years preceding August 31, 1906, shows that at that time there was 13,143,738 acres of surveyed public-school lands owned by the State, in addition to a considerable acreage of unsurveyed school land commonly called "public domain or scrap land." Three-fourths of this acreage is situated in the trans-Pecos region, and is not well adapted to agricultural uses because of its mountainous character and the present scarcity of available water. Mr. Terrell states in his report that the

total area of school land approximates 44,000,000 acres. Mr. W. H. P. Hunnicutt, chief draftsman of the Texas land office, on August 11, 1908, writes:

> The public free school lands controlled by the State yet unsold amount to approximately 6,500,000 acres. The average price per acre at which it is being offered is $1.50.
>
> The State University owns and controls 2,000,000 acres, but is not offering any of it for sale. I estimate the average value of that land per acre at $2.50.
>
> This office has no printed summary showing unsold land and prices. Sales are being made every day and such a summary would be impracticable.

The report of the commissioner of lands for 1906 shows that nearly 7,000,000 acres of school land had been leased to individuals for grazing purposes at that time, at prices ranging from 3 to 7 cents per acre. Practically all leased for 3 cents (4,875,434 acres) was leased prior to 1903. Much of the acreage of public land west of the Pecos is classed as mineral land and carries with its purchase a different minimum price from that borne by agricultural land. The absence of any complete topographical map of this area makes it difficult, however, to definitely state whether or not the classification in many individual instances is correct. There is still a small area of public land in eastern Texas which is classed as timber land, but very little of this now bears timber of any particular value.

Texas has no state engineer and none of the state departments is charged with the collection of data regarding the distribution of the cultivated and uncultivated acreage of arable, irrigable, forest, and waste land in detail, nor with a compilation of the areas irrigated and the unoccupied areas of good land under ditch now ready for settlement. The data given for various irrigation systems under the head of irrigation enterprises in this report contain partial answers to some of these questions, and doubtless the recently created department of agriculture for the State will be able to furnish other data later. Formerly this department was simply a branch of the department of agriculture, insurance, statistics, and history, but funds for the collection of data along the above lines have not been available in sufficient quantity to cover the field. In spite of this fact the department has issued statistical reports, the last to be printed being issued in 1905.

PRODUCTS OF IRRIGATED LANDS.

Because of the wide variation in climatic and other natural conditions it is not possible to summarize results regarding irrigated, or nonirrigated products for that matter, for the State of Texas in such a way as to give even approximately fair average results. In some localities nonirrigated crops will produce nearly if not quite as much as the same crops under irrigation in other localities. Under the

descriptions of the various irrigation enterprises will be found in some cases comparisons made by irrigators. It will be noticed that in some instances wide variations in the quantities and values of irrigated products even for the same locality exist in these descriptions.

In answer to an inquiry as to the character of crops grown, or to be grown, on the largest irrigation system in the State, Mr. W. S. Chaplin, president of the American Rio Grande Land and Irrigation Company, says "anything that grows." This is too strong a statement, perhaps, to be taken literally for any one section, but his answer comes very nearly applying to the State as a whole. Apples, for instance, would probably not flourish on the lower Rio Grande, though they do well in the vicinity of Denison and elsewhere in the northern portion of the State.

The list of products which can be grown successfully is rapidly being extended, and many which a short time ago were considered entirely foreign to the State are found to flourish, especially under irrigation. Some semitropical fruits and vegetables do well in the lower coast country, and oranges, grapefruit, dates, olives, bananas, kumquats, tangerines, etc., have been tried with some success. Tea growing has been experimented with in one locality by the U. S. Department of Agriculture, but the experiment has been abandoned. This does not prove, however, that it can not be made a success in some other portions of the State. Near Wharton the Department is now experimenting with camphor, and in one place at least in the trans-Pecos region a factory is in operation which is producing commercial rubber from the guayule shrub. On the lower Rio Grande the hennequin fiber plant is being cultivated for rope-making purposes, the fiber being of unusual length and strength. In the Pecos Valley European grapes are being tried and when grafted on native resistant stock are found to do exceptionally well. Formerly large quantities of the Mission grapes were grown in the El Paso Valley, but on account of the scarcity of water since the heavy drains made upon the Rio Grande higher up the river, large vineyards have been abandoned. Possibly, however, they may be cultivated again after the Rio Grande project of the Reclamation Service shall have been completed.

In certain portions of east Texas, as at Willis and Nacogdoches, it has been demonstrated that a fine grade of tobacco can be grown. The Galveston News of August 16, 1908, puts Texas third in point of value per acre of tobacco crop. Florida leads with $416.25 an acre; Georgia follows with $344; and Texas third, with $210 per acre. Twenty-two other States fall below this, and the average assigned for the whole United States is $86.75. In tobacco culture, as in many other agricultural lines, Texas is but a beginner, ranking

twentieth among the States in production and twenty-first in acreage; but more encouraging results are to be expected as experience is gained.

As illustrating the difficulty of comparing irrigated and nonirrigated products, it is stated on the best authority that in the San Angelo country nonirrigated cotton generally yields one-fourth to one-half bale per acre, but under irrigation 1 to 1½ bales per acre is common. On the lower Brazos and Colorado bottom lands 1 bale and sometimes 2 bales per acre were not uncommon before the advent of the boll weevil, without the least attempt at irrigation. In Grayson County, in the vicinity of Sherman, Mr. R. E. Smith, who is entirely dependent upon natural rainfall, raises large quantities of alfalfa with almost as large a yield per acre as can be gotten in some other localities under irrigation.

The people of the State are awakening to the value of diversification, and to a large extent the "one-crop" plan is already giving place to variation in the character of the agricultural products. The benefits are easily seen in the increased prosperity and the increasing number of small farmers who are beginning to learn that it pays to raise many things for home consumption for which a market has not yet been established. In many localities the difficulty of getting products to market has so far limited the variety of perishable products which can be successfully grown, but increasing transportation facilities and increasing growth of comparatively near-by cities are rapidly tending to minimize this difficulty.

HISTORY OF IRRIGATION DEVELOPMENT.

The beginning of irrigation in western Texas antedates any records so far found, and it is probable that in no portion of the United States is the practice older. Scanty and irregular distribution of rainfall was doubtless the cause of its use in the beginning, and even at later dates, when unnumbered acres of fertile lands could be had for little more than the trouble of preparing them for cultivation. Coronado, on his journey northward in the early part of the sixteenth century, found well-established systems of irrigation in the vicinity of El Paso, utilizing water from the Rio Grande on both sides of its present channel.

Tradition tells us that the Pueblo Indians of Ysleta claimed that ancient irrigation systems of great extent were built centuries ago by the Yuma Indians on the Pecos River in the vicinity of Pecos and Grand Falls, but the constant raids by the Comanche and Apache Indians caused them to move on to the valley of the Rio Grande, only to be followed there by their old enemies and forced to move out to the Colorado of the West. In the vicinity of Toyah Springs

evidence is found indicating that these waters were used for irrigation purposes long before the first white man found his way there.

At San Antonio, when the Franciscan fathers founded their missions they directed the construction of canals or acequias by the Indians. These canals were used not only for supplying water to the missions for domestic purposes, but for irrigation as well. Among the ditches constructed between the years 1716 and 1774 may be mentioned the Concepcion, Alamo, San Jose, San Juan, and Espada.[a] In 1730 the San Pedro ditch was built by immigrants from the Canary Islands and was used for conducting water to the cultivated fields.[a]

At old Fort San Saba, near Menardville, the remains of an irrigation system, constructed in 1774, also by the Franciscan fathers, can still be traced.[a]

As early as 1852 the fourth legislature passed an act relative to irrigation. In 1882 the seventeenth legislature passed an act making large grants of land for the construction of irrigation ditches. There were several classes and the number of sections of land granted per mile of ditch varied with the class. In 1889 and in 1895 additional regulations were established with a view to encouraging irrigation. The result of some of these enactments was the projection of numberless irrigation schemes, many of which were "boom" propositions from the start, while others proved failures when constructed because of the lack of sufficient hydrographic and other data.

Irrigation along the lines now practiced began to develop first in western Texas. The first ditch in the vicinity of Del Rio was constructed in 1868, another in 1869, and another in 1874. On the Pecos, one of the present large systems was built in 1875, another in 1887, and another in 1896. It might have been expected that the older systems in the vicinity of El Paso would have suggested earlier extensions under present methods, but work of this character did not become active until about 1889 to 1891. At Fort Stockton and for the Nueces drainage area it began as early as 1876. On the Concho, San Saba, Llano, and other tributaries of the Colorado River irrigation systems began to spring up about 1875, and possibly earlier, and these were added to about 1879, but this work became most active in the nineties.[b]

Along the lower Rio Grande not a great deal appears to have been done on a large scale until about 1896, but since that time irrigation development in this section has been extremely rapid, especially during the last few years.

At San Antonio the Upper Labor ditch was built about 1776 and served a large acreage; the Concepcion was built in 1729 and served

[a] U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 71.

[b] Data derived principally from U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 71.

continuously until 1869, when it was abandoned. The Espada, built by the Spanish in 1824, was abandoned about 1880 or 1885, but was revived in 1895.[a] In the vicinity of San Antonio irrigation from artesian wells began about 1884 and was extended rapidly during the nineties. These wells are of various depths, some being in the neighborhood of 1,500 feet. At Waco a flowing well, 1,850 feet deep, was put in operation for irrigation purposes in 1896.[a]

In eastern Texas, where the rainfall not infrequently exceeds 50 inches per annum, one would not normally expect to see irrigation practiced on a large scale, but the reverse is the case. A clipping from some journal, the name of which was not ascertained, gave in very few words an explanation of the reason for this condition. The following is a copy of the clipping:

History of Texas rice industry in brief.

Brought to Texas by first settlers.
110 acres in cultivation in 1850.
135 acres in cultivation in 1890.
8,711 acres in cultivation in 1900.
250,000 acres in cultivation in 1908.
8,206 acres in cultivation in Orange and Jefferson counties in 1900.
75,000 acres in cultivation in same counties in 1908.
Jefferson County produces one-eighth of rice harvest of this country.
200 miles of canals in Jefferson County. Five largest rice mills in the world.
Annual value of crop to Jefferson County, $2,000,000.
$700,000 invested in mills.
$4,000,000 invested in rice production.

Neither time nor opportunity admits of the verification of the above figures in detail, but the total acreage stated for 1908 is a little above the estimate of Mr. A. E. Groves, secretary-treasurer and manager Texas Rice Farmers' Association and Exchange, of Houston, which placed it at about 225,000 acres. In point of money invested and in extent of area covered, rice irrigation exceeds any other class of irrigation in the State, and possibly all of the others combined.

The methods employed in Louisiana and Texas differ radically from the older methods in use in South Carolina and Georgia, where periodic variations of the water level in tidal rivers make it possible to flood the lands or drain them through the same channels by merely opening gates or "trunks" at the proper stages of the water in the rivers. In Louisiana and Texas pumping, often against high heads, had to be resorted to, but the differences possible in the methods of preparing the land and in harvesting the crop demonstrated that the methods could be made to pay. Following the lead of Jefferson County in the early nineties, the cultivation of rice spread rapidly southwestward. About 1899 Eagle Lake, near the town of the same

[a] U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 71.

name, was first drawn on for rice irrigation and the practice spread rapidly down the Colorado River, until now the acreage in rice below Eagle Lake approximates and may exceed 50,000 acres. Later still, the Brownsville section began to be developed and has made more rapid progress in irrigation than any of its predecessors, developing the cultivation of rice, fruits, truck, and all sorts of staple products. Its future possibilities are as yet indeterminate.

Coming a little later than the first large canal system, and developing at perhaps a faster rate, shallow wells have been employed as a source of water supply. Their use has been confined largely to rice irrigation. These have increased materially the area available for irrigation, by taking in lands lying between the larger streams and more or less out of reach of many of them, and they have extended the field much farther inland upon higher topographic lines.

Along the Coastal Plain, particularly near Alvin, Beeville, and in the Brownsville region, attempts have been made to raise citrus and other semitropical fruits, which a very few years ago was not thought possible. Oranges, grapefruit, kumquats, tangerines, olives, dates, and figs are grown to some extent in the coast country, with and without irrigation, and further experiments will undoubtedly add other fruits. Irrigation has done its full share and will do more in the future to help in this line, not only in the coast country but in other portions of the State.

The area of Texas is so great that the field of existing developments has been barely touched upon, and it would require the careful, detailed study of each section to even approximate a reasonably correct statement of existing conditions. The published data available, while valuable, is not up to date, and busy men find it hard to take the time necessary to answer questions sent them by mail. Moreover, much of the work which has been done has not been recorded in available form even by the larger canal companies, so that it would require much time and patience to determine costs of existing systems where fairly well appointed offices are maintained. For the smaller systems and private enterprises it is even more difficult to arrive at correct values. Mr. C. B. Metcalfe, of San Angelo, evidently at the cost of considerable time and with the aid of an intimate knowledge of existing conditions in his section, has sent in a list of 83 irrigators in his section, who irrigate 5 to 700 acres each. Without this list less than 20 per cent of the names even could have been obtained. This will serve to illustrate the difficulty of approximating the present status of irrigation in Texas, much less to venture a guess at what the future may show.

IRRIGATION ENTERPRISES.

Considerable published data can be found relating to irrigation in Texas, but in some sections of the State material changes have been made in many of the plants since these descriptions were written. For this reason and because of a lack of space, the detailed descriptions in this report will be confined to those cases where the data were obtained directly from the owner or some officer of the company in the case of chartered organizations, or from someone who is conversant with the system and who is competent to give a correct description. For convenience, the State has been divided into arbitrary groups or divisions, as follows:

Group I.—That part devoted principally to rice culture. The area covered extends from the Sabine River to the Guadalupe River along the coastal region and as far inland as information could be obtained to the effect that rice was grown.

Group II.—All the coastal area from Beeville to Brownsville, covering the various systems on the lower Rio Grande and intervening territory.

Group III.—The area lying in the vicinities of San Marcos, New Braunfels, San Antonio, Seguin, Batesville, Laredo, Eagle Pass, and Del Rio.

Group IV.—The area in the vicinity of Wichita Falls and to the northwest of that point.

Group V.—The several small plants which cover the regions about Llano, Junction, Menardville, San Saba, Lampasas, Brownwood, San Angelo, and Abilene.

Group VI.—The Pecos Valley, Toyah, and Fort Stockton districts.

Group VII.—The Rio Grande Valley in the vicinity of El Paso and as far down as Presidio and Brewster counties.

GROUP I.

Because of the magnitude of the area covered by irrigated rice farms, the amount of money invested, and total annual returns, this group has been placed first. The following descriptive notes cover only those systems for which recent data are available, though other systems of equal or greater magnitude may exist in the territory. These are included also in the tabular statement which will be found at the end of the discussion for this group.

The Adams Bayou Canal Company.—This company has its main office at Orange, Tex. It is incorporated and has $50,000 paid up capital stock. Water for the canal is drawn from Adams Bayou and Sabine River, the lift being 17 feet. A centrifugal pump, with two 30-inch double-suctions and a 36-inch delivery, with an extra

pump on each side of the impellers, is driven by a 150-horsepower slide-valve engine, for which steam is furnished by boilers having 200 horsepower capacity. The pump is rated at 50,000 gallons per minute. The cost of pumping plant, including tankage for 2,000 barrels of fuel oil, is given as $15,000, and the cost of fuel oil per season as $5,000. The daily run for one hundred days averages fourteen hours, and the annual cost per acre for water, including labor, fuel, etc., for the 4,000 acres served, amounts to $3.50.

There are 5 miles of main canal, which is 150 feet wide for 2 miles and 100 feet wide for the remaining 3 miles. The side slopes are 1½ to 1. There are about 4 miles of laterals, having side slopes of 2 to 1 and varying in width from 80 to 24 feet. Mains and laterals cost $35,000, and the annual cost of maintaining these is given as $1,500. The water is diverted to the land by means of wooden gates about 3 feet wide, set in the levees. Four thousand acres were watered in 1908, and it is expected that the same acreage will be covered in 1909, but the canal can be made to cover an additional 4,000 acres. It is estimated that the amount of water applied during the irrigation season equals 850,000 gallons per acre—equivalent to 2.53 acre-feet per acre per annum, or a depth of a little more than 30 inches—and the average rainfall amounts to only 544,000 gallons per acre during the rice growing season, or about 20 acre-inches per acre. The former figure is probably too high and the latter figure too low.

The water rent is given as 2 sacks of rice per acre and the average yield as 8 sacks, the crop being marketed at local mills and in New Orleans. The average cost of preparing the land is placed at $5 per acre and the cost of producing and marketing the crop at $10 per acre. For favorable seasons it is estimated that a net return of $8 per acre would represent a fair average.

Unimproved lands in the vicinity have increased from $5 to $30 per acre. One man, with some help during harvest time, can care for 125 acres, and it is estimated that he would need about $2,500 to make a start. It is estimated also that about 12,000 acres will be cultivated in the vicinity during 1909 and that there are 20,000 acres of rice land in Orange County uncultivated. Ultimately it will be possible to irrigate 40,000 to 50,000 acres. Under this system there is room for 100 additional farmers to raise rice and garden truck.

The Port Arthur Rice and Irrigation Company.—Water is lifted 17 feet from the Neches River by means of an 18-inch, two 24-inch, and two 36-inch pumps, with a rating of 150,000 gallons per minute. The cost of construction was about $80,000.

The main canal is 1.5 miles long and 200 feet wide, and there are 24 miles of laterals. The cost of these was about $70,000 for construction, and the annual cost of maintenance about $2,000. Head

gates and boxes are used to divert the water from the canal and the water is not measured. The water rental is 360 pounds of rice (2 sacks) per acre, and the irrigation season is said to last from May to October.

Unimproved land before irrigation was worth $5 to $10 per acre in the vicinity, but when subject to service from the irrigation canal is worth $25 to $40. The average yield is placed at 12 barrels of 162 pounds each. The crop is marketed in Port Arthur, Beaumont, Houston, and New Orleans. There were 8,650 acres in cultivation in 1908, and 12,000 acres can be brought under canal. The average cost of producing and marketing crop is placed at $20 to $25 per acre and the average value of same at $30 to $50 per acre, while the average net return is $10 to $25 per acre. Only rice is produced. One man can manage 100 acres, and the average funds and equipment are placed at $1,200 for this purpose. The opportunities for settlement are good for dozens of real farmers.

The McFadden, Wiess, and Kyle Land Company.—Water is lifted 27 feet from the Neches River at Beaumont by means of four rotary pumps, direct-connected to four 250-horsepower Corliss engines. Each pump has a rated capacity of 35,000 gallons per minute. There are 30 miles of main canals, and the cost of plant, canals, etc., was approximately $250,000.

From the laterals water is diverted through gates upon the land, and the water rental is 2 sacks of 180 pounds each per acre. The duration of the irrigation season is given as about four months. During 1908 there were 17,500 acres under rice and the area for 1909 will probably be the same, though 20,000 acres can be brought under canal.

Unimproved lands before irrigating were worth $5 per acre, but afterwards about $10, while the value of irrigated lands is about $30. The average yield is 10 sacks of 180 pounds, and this is marketed at the mills. The average cost of producing and marketing the crop is stated as $27.25, the average value as $35, and the average net return as $7.75 per acre. One man should handle 100 acres, and the average value of equipment necessary is placed at $1,000. The opportunities for settlement are good, and it is estimated that 1,000 settlers could be accommodated in the vicinity. The estimate for the probable total number of acres to be irrigated in the vicinity during 1909 is placed at 50,000, while the ultimate acreage is put at 100,000.

The Beaumont Irrigating Company.—Water is taken from Pine Island Bayou, a tributary of the Neches River. The first lift is 31 feet. Five miles south of this is a second lift of 10 feet. At the first lift are five rotary pumps and at the second lift two rotary and two centrifugal pumps. The total pumping capacity is given as 140,000

gallons per minute. Crude oil is used for fuel. The cost of construction was not obtainable.

The main canal is 150 feet wide from center to center of the levees, which are about 4 feet high, have 4-foot crown, and a side slope of 1.5 to 1. The grade is level for the first 2 miles and drops 2 feet in the next 10 miles. The main lateral, known as the "check lateral," is 14 miles long and falls 13 feet in that distance. It is 60 feet from center to center of the levees, which have 3-foot crown, side slopes of 1.5 to 1, and average 3 feet high. There are 26 miles of additional laterals, 40 feet wide from center to center of the levees. All laterals slope about 1 foot to the mile. The cost is not obtainable. The total cost of maintenance is stated as $12,000 to $15,000 per annum, but this probably includes operation of pumping plant.

The water rent is 2 sacks (4 bushels) of rough rice of 180 pounds each, and the irrigation period lasts from three to four months. The water is not measured and is distributed to the land through small laterals, and the actual flooding season varies from thirty-five to sixty days' actual pumping. About 16,000 acres of rice were planted in 1908 and the probable number for 1909 is at least as great. At least 30,000 acres can be brought under canal.

Unimproved lands before irrigating were worth about $5 to $6 per acre, and the present value of unimproved, undrained land in the vicinity is about the same. Drainage is being provided for much of the land, which enhances its value considerably. Irrigated lands are worth $20 to $35 per acre, depending upon location, railroad facilities, etc. Ten sacks of rough rice constitute an average crop. It is marketed in New Orleans, Lake Charles, Beaumont, Galveston, and Houston. The average cost of preparing land and sowing the crop is given as $4 to $5 per acre, and it costs on an average $27.25 per acre to produce and market a crop. The average value of the crop is $35 per acre, and the average net return is $7.75 per acre.

One man can cultivate 100 to 125 acres of rice, and needs for the purpose four mules, worth $600 to $800; binder, $160; drill, $75; plows, $30; drag harrow, $8 to $10; disk harrow, $30; wagon and harness, $50. If large areas are cultivated, $3,000 for a traction engine should be added. Thrashing costs from 25 to 30 cents per sack for those not owning separators. In addition to the above equipment, the beginner should have a cash balance sufficient for maintenance of self and family for one year, with a margin for emergencies. The opportunities for settlement are good, and perhaps 100 additional families could be cared for on this canal. Honest, industrious men with some money are wanted. Mr. A. C. Love, engineer for the company, estimates that there are 100,000 acres of land in Jefferson County alone which are available for rice irrigation. He also adds that there is a disposition on the part of the canal companies

owning land to cut it up into small tracts and sell on easy terms to actual farmers, one company now being engaged in making arrangements to cut up some 10,000 acres for this purpose.

The Neches Canal Company.—The Neches Canal is located in the northern portion of Jefferson County and draws water from Pine Island Bayou, a tributary of the Neches River, from which it is lifted 35 feet at the bayou, and 2 miles back from the bayou is a second lift of 10 feet. At the first lift are six rotary pumps of 35,000 gallons per minute rated capacity each, for which steam is furnished by three 900-horsepower water-tube boilers. At the second lift are two 70,000-gallon rotary pumps and one 70,000-gallon centrifugal pump. There are three 300-horsepower water-tube boilers. Oil is used for fuel at both plants. Pumping begins about May 15. The cost of pumping plants and canal systems is given as $600,000.

There are 27 miles of main canal, 156 feet wide from center to center of the levees, which have 6-foot crown and side slopes of 2 to 1 inside and 1.5 to 1 on the outside. The slope of water surface is 1.5 inches to the mile. There are 30 miles of laterals, which have 4-foot crowns to the levees and side slopes of 1.5 to 1 inside and out. They cost $750 per mile to construct. The annual cost of maintenance is given as $20,000. The water applied to the land is not measured, and is diverted by common water gates, the rate of water rental being $6 per acre per annum. The irrigation season lasts about one hundred days. No data were given as to the amounts of water applied. The rainfall averages 7 inches during the irrigation season. During 1908 about 21,000 acres of rice were planted, and it is estimated that 29,000 acres will be planted in 1909; also that 100,000 acres can be eventually brought under canal. Before irrigating, the price of unimproved lands was $2 per acre; it is now $20, if within reach of water. Irrigated lands are worth $25 per acre. It costs $5 per acre to break the land, disk, harrow, seed, and make levees, and the average production is 10 sacks of rough rice. The crop is marketed in Beaumont, Houston, Galveston, and New Orleans. A rough estimate of the average cost of producing and marketing the crop is $27.25, and the average value $35 per acre, the average net return being stated as $7.75 per acre. The average number of acres which can be cared for by one man is given as 150, for which it is estimated he will need $1,500 for equipment.

The opportunities for settlement under this canal are limited by reason of the canal having all it can handle. Mr. C. W. Rollins, engineer for the company, estimates that 100,000 acres can be irrigated eventually in this section.

The Lone Star Company.—This company takes water from the Trinity River at its mouth. The lift is 23 feet. Three 24-inch centrifugal pumps deliver 70,000 gallons per minute and are driven by

three Corliss condensing engines, for which steam is furnished by three water-tube boilers of 256 horsepower. Including the intake, the pumping plant cost $45,000. There are 8.25 miles of main canal, 80 feet wide from center to center of the levees, and having an 8-foot berm, the center being cut out 1.5 feet deep. The side slopes are 2 to 1 on the inside and 1.5 to 1 on the outside. The canal was built on a grade of 1 inch to the mile. The cost was about $4,000 per mile. There are about 27 miles of laterals having same side slope as the main canal, but a fall of 1.5 feet to the mile. These cost $2,000 per mile. The cost of maintaining main canals and laterals is given as $500 per annum.

The water rent is one-fifth of the crop and the water is distributed to each field by gates, no measurement being made. The length of the irrigation season is given as one hundred days and the estimated amount of water applied is 30 to 35 inches. This appears to be high. The estimated average rainfall is 4 to 8 inches. During 1908, 10,150 acres of rice was under cultivation and the probable area for 1909 is 12,000 acres. The number of acres which can be served by the canal on one lift only is estimated at 50,000. Unimproved land in the vicinity was worth from $5 to $8 per acre before irrigation, but is now worth $15 without water, or $25 if water is available. The value of irrigated lands is placed at $40 per acre. The average yield is put at 11 sacks, or 44 bushels. The crop is marketed in Galveston, Houston, Beaumont, and New Orleans.

The cost of buildings, fences, etc., necessary before irrigating is estimated at $50 per acre, and the cost of producing and marketing the crop is divided as follows:

Cost to the farmer, who gets three-fifths of the crop if he rents		$12.50
Cost to the canal company, which gets one-fifth of the crop		4.00
Cost to landowner, who gets one-fifth of the crop		1.00
Total		17.50
Average value of crop, $33, divided as follows:		
To the farmer	$19.80	
To the canal company	6.60	
To the landowner	6.60	
		33.00
Average net return		15.50
Distributed as follows:		
To the farmer	7.30	
To the canal company	2.60	
To the landowner	5.60	
		15.50

The average cost of equipment required for 100 acres is put down as $900 for six mules and harness and $270 for implements, a total of $1,170, and one man can handle 115 acres of rice. To the above-named amount for equipment should be added $1,400 expense for

one year, making the sum needed to make a "one-man" start $2,570. The expenses can be reduced $250 by raising one's own seed rice. The opportunities for settlement are good for good men, wheat farmers preferred. In three years' time it is expected to bring 20,000 acres under the canal, and more is available. For this acreage 75 additional families will be needed.

Barges are used for the transportation of rice on the main canal, the capacity of each barge being 300 sacks (a carload). Each year 20,000 sacks are transported in this way. B. H. Collins, of Anahuac, states that drainage is absolutely necessary to raise rice successfully:

> We have put into force a rule that we will not water land without improved drainage. We have a ditching machine that makes a ditch 8 feet wide on top, 3 feet deep, and 20 inches on the bottom, proving very successful. There is opportunity for great improvement in seed. With C. B. Allaire, of San Antonio, N. Mex., we are this year conducting experiments along the lines of Professor Neilsen, of Sweden, with other grains. Just starting this year. Expect definite results in 1909. We get good results from pure bone meal and other fertilizers, which increase the yield from 3 to 5 sacks. The cost of fertilizer is $1 per acre, paid by landowner. We had 200 acres fertilized in 1907 and 4,500 acres in 1908.

The Cane and Rice Belt Irrigation Company.—This canal is located in Fort Bend and Harris counties and takes water from the Brazos River about 20 miles above Richmond. The water is first lifted 25 feet into Jones Creek, which parallels the river, and 17 miles below is again lifted 9 feet into a canal. The total cost of machinery, dams, canals, and right of way amounted to $250,000. There are two 45-inch centrifugal pumps at each lift. These have a normal capacity of 100,000 gallons per minute, and it is estimated they can be made to deliver safely 150,000 gallons per minute. Fuel oil is used. This entire plant is new, being used during the season of 1908 the first time.

Jones Creek acts as a reservoir, 17 miles long. The main canal is 10 miles long and has a capacity sufficient to water 25,000 acres. There are about 8 miles of laterals, having a slope of about 0.7 foot to the mile. The cost of maintenance of canals and laterals was placed at about $1,000 per year. Water is diverted to the land through 24-inch corrugated iron boxes, and the annual rental is $6 per acre. The irrigation period lasts from about May 15 to September 10.

During 1908 there were between 6,000 and 7,000 acres under rice and sugar cane, and the probable acreage in 1909 is placed at 15,000. The ultimate area which can be brought under canal is put at 60,000 acres. The value of unimproved land before irrigating was $10 per acre, but when water can be had the land is usually sold at $20 to $30 per acre. Other unimproved land is valued at $10 to $15, and the value of irrigated lands is placed at $20 to $50 per acre.

The average yield is placed at 15 barrels of rice (160 pounds per barrel) and 30 tons of sugar cane. Houston and New Orleans are the market points. The cost of preparing land for irrigation is $4 per acre, and the average value of crops is placed at $3 per barrel for rice and $2.25 per ton for cane. One man can manage 100 acres of rice or 20 acres of sugar cane up to harvest time.

The opportunities for settlement are good, and there is room under the canal for enough to take up 8,000 acres, Germans or good Americans preferred.

The Buckeye irrigation farm.—The lift from the Colorado River at Buckeye is 20 feet. The pumping plant consists of two vertical cross-compound, 400-horsepower engines, each connected to a 32-inch centrifugal pump. The combined capacity of the two is 75,000 to 80,000 gallons per minute. Fuel oil is used for steaming purposes. The plant is modern, using all possible economies. The main canal is 200 feet wide for 2 miles and 120 feet wide for 5 miles. The side slopes are 2 to 1, built with earth taken from inside of the levees. There are 8 miles of laterals and sublaterals varying from 15 to 40 feet in width. The water is distributed to farmers as needed and the irrigation period is stated to be from May 15 to August 15, on an average. The system has been idle during 1908 and no acreage is given for 1909, but it is estimated that 20,000 acres can be brought under canal. Unimproved land before irrigation was valued at $15, and the present value of unimproved lands in the vicinity is estimated to be $50 per acre. The cost of preparing a complete drainage system for the land is estimated at $2.50 per acre. Rice is the only crop grown, the average yield being 10 sacks; cost of production, $27.25; value of crop, $35; and the net return, $7.75. Buyers come to the section during the marketing season.

One hundred acres is sufficient for one man, and the cost of cultivating the same is placed at $1,000. The amount suggested as being necessary for making a successful "one-man" start is $2,000. The opportunities for settlement are good and 1,000 families is the number given for which there is room. The probable number of acres to be cultivated during 1908–9 in the vicinity is stated as 15,000, the ultimate available acreage being put at 25,000.

The Security Rice and Irrigation Company.—This plant is situated 6 miles southwest of Bay City, in Matagorda County. Water is lifted 8 to 10 feet from the Colorado River by means of a 45-inch pump of 48,000 gallons per minute rated capacity, with two 125-horsepower high-pressure boilers. Fuel oil is used for steaming purposes. The cost of the plant was not obtainable.

The main canal is estimated to be 10 miles long, 80 feet wide from center to center of the levees, which have side slopes of 1.5 to 1. Capacity is 150,000 gallons per minute and cost was $25,000. There

are 4 miles of laterals, 50 feet from center to center of the levees, which have side slopes of 1.5 to 1, with a capacity of 100,000 gallons per minute. The cost of construction is estimated to have been $8,000.

Water is turned upon rice fields until the farmers are satisfied. The method is characterized as crude and expensive, but it is the one in general use. The water rental is one-fifth of the crop and the irrigation period lasts from ninety to one hundred and ten days. The estimated amount of water applied averages 11 gallons per minute per acre during the season. There were 3,000 acres planted to rice in 1908 and probably 6,500 acres in 1909, while the area which can be ultimately brought under canal is 10,000 acres. Unimproved lands before irrigating were valued at $18 to $30, and the present value is placed at $20 to $30. It is stated that after irrigating the value does not improve greatly, as the land deteriorates for rice culture after three or four years because of the increased growths of water grasses which smother the rice. The cost of preparing land for irrigation is itemized as follows:

Plowing	$2.50
Disking and harrowing	1.50
Planting	.40
Pushing levees	.40
Total	4.80

Ten sacks constitute an average crop, and it is marketed in Bay City. The average cost of producing an acre of rice, including all cost—water rent, land rent, etc.—is $27.50, the average value of the crop $35, and the average net returns per acre $7.50. The average number of acres which can be handled by one man is estimated to be 75, and the equipment needed is 4 mules and harness, 1 heavy wagon, 1 drill, 1 disk harrow, 1 sulky plow, 1 drag harrow, 1 binder, 1 wooden push with chains, etc., and $1,500 in money.

The opportunities for settlement are said to be fair and the probable number of settlers who could be accommodated in the vicinity is estimated to be 500 to 1,000—a very high estimate—and the class of settlers wanted is given as "farmers." The probable area to be irrigated is given as 6,500 in 1909 and the ultimate acreage at 10,000 acres. Evidently these figures relate to this canal system, while the estimate of the number of settlers must apply to the whole system.

The Tres Palacios Rice and Irrigation Company.—This system is situated in Matagorda County, on the west side of the Colorado River, 4 miles below Buckeye, on the St. Louis, Brownsville and Mexico Railroad. Water is pumped from the Colorado River against an average head of 25 feet, the maximum being 32 and the minimum 7 feet. There are two 36-inch centrifugal pumps direct-connected to cross-compound condensing engines of 500 horsepower each.

There are two 300-horsepower boilers and two 250-horsepower boilers. Engines and pumps are set in a brick pit 14 feet deep. The plant cost approximately $80,000. Crude oil from Texas fields is used for fuel and cost $1.35 per barrel in tank at plant in 1907. The plant consumed 1.4 barrels of oil per acre irrigated—a cost of $1.89 per acre for fuel alone. The total cost of operating system during 1907, including superintendence, hauling, storing, and selling the crop, was $21,500, and the total receipts were $40,000.

There are 7.1 miles of main canal, 108 feet from center to center of the levees, and the longitudinal slope is 1.6 feet per mile. The carrying capacity is 200 cubic feet per second. Cost of construction, $18,000. There are 16.7 miles of laterals, 30 to 50 feet between centers of levees, which average 2 feet in height, and the cost of construction was $11,000. The fall varies from 1 to 7 feet per mile. Accurate records of cost of maintaining canals and laterals were not kept. Water is diverted to the land by means of gates, which are opened by a canal rider upon request of the farmer and allowed to remain open until the latter is satisfied. The water rental is one-fifth of the crop, but there is a movement on foot to change this to a money rental of $6 per acre. The duration of the irrigation season is given as four months—that is, the plant is run that length of time—and the amount of water applied is estimated to be 3.1 feet in depth, or 7 gallons per minute per acre. This appears to be too high, but more water is needed in the Colorado Valley than in the vicinity of Beaumont.

In 1907, 4,500 acres were planted, 8,000 in 1908, and probably 8,000 acres in 1909. Rice only is grown. Probably 50,000 acres could be covered by extending the canal, but the water is now limited to 10,000 acres. Unimproved land before irrigating was worth $2.50 to $10, and after irrigating, $15 to $20, while lands under irrigation are worth from $20 to $40 per acre. The cost of preparing land for irrigation varies from $0.50 to $4, depending upon the number of contour levees and drain ditches necessary. The crop averaged 10 barrels (of 162 pounds) in 1907, most of which was sold to local mills. The average cost of producing and marketing the crop is put at $27.25 per acre, the average total value at $35, and the average net return to the farmer at $7.75 per acre.

It is estimated that 150 acres is a fair apportionment per man. At least $3,500 is necessary for starting, if operating on a cash basis, but many farmers make crops on half this amount by getting advances.

Travis L. Smith, jr., of Eagle Lake, who was manager of this system during 1907, considers the rice industry practically developed up to its limit in this vicinity unless reservoirs are installed.

The Colorado Canal Company.—This company draws its supply of water from the Colorado River at Bay City by means of a 48-inch pump and another large pump, driven by two triple-expansion

engines. There are two boilers which use oil for fuel. The nominal horsepower of the engines is 200 and 275, respectively. There are two water heaters and two condensers, and the practical capacity of the pumps is 125,000 gallons per minute against an average lift of 10 or 10.5 feet. The cost of all installation work was $44,840.

The main canal is 14 miles long, has side slopes of 1.5 to 1, and varies from 150 to 100 feet between centers of levees. The height of the levees varies from 2 to 8 feet, depending upon the topography. There are nine locks and two trestle flumes of 260 feet each, and 19 miles of laterals, varying from 60 to 10 feet in width, on a fill varying from 1 to 4 feet. Main and laterals cost $96,400 for construction. The average cost of maintaining the main canal, laterals, and plant is estimated at $2,000 per year. Water is not measured, but the rice is kept flooded as needed. The water rental is $6 per acre per annum and the pumping season lasts from about May 1 to September 30, depending upon the dates of plantings. The crop matures in about ninety days. There were 7,800 acres planted to rice in 1908 and probably 8,000 in 1909, while the ultimate acreage under canal can be increased to about 15,000. The value of unimproved lands before irrigation is about $20 per acre and upward, while the value of irrigated lands is as high as $45 per acre. To prepare the land for irrigation costs $5 per acre and upward, depending upon the land and the character of the house, barn, etc. The average crop is 10 barrels of 162 pounds each, sometimes reaching 20 barrels. This is marketed in Bay City. The average cost of producing and marketing the crop is $20 per acre. This includes plowing, disking, seed, water, cutting, shocking, thrashing, sacks, hauling, and storage, on the basis of a 10-barrel crop. The average value of the rice is $2 to $3.75 per barrel, depending upon the grade, and sometimes $4 is realized for first-class fancy rice. The average area to be handled by one man is 100 acres, for which 4 mules, a plow, a seeder, a binder, etc., with an aggregate value of perhaps $1,000, together with about $200 for seed rice and an additional amount for feed for teams and maintenance of family until harvest. Banks and warehouses will make advances to proven men. Honest, hard-working, intelligent settlers are wanted to purchase 160-acre tracts. It is estimated that 45,000 acres were irrigated in the vicinity in 1909. No ultimate acreage has been stated.

The Northern Irrigation Company.—Water is taken from the Colorado River, near Markham, and the capacity of the pumping plant is estimated at 100,000 gallons per minute. The length of the main canal is 8 miles and that of the laterals 12 miles. No other data were obtained.

The water rental is one-fifth of the crop and the length of the irrigation season four months; the rainfall during the crop-growing

season is almost nothing; the area irrigated in 1908, 9,000 acres, and the probable area for 1909, 6,000 acres. Unimproved lands are valued at $25 before irrigation and irrigated lands at $40 per acre. Rice is the exclusive crop, and the average yield is estimated at 12 sacks per acre. This is sold in Markham, and the average value of the crop is about $40. Probably 100 good farmers could be accommodated in this vicinity.

The Eagle Lake Rice Irrigation Company.—The water supply for this system is derived from Eagle Lake, 2 miles south of the town of Eagle Lake, and also from the Colorado River. The lake covers 2,000 acres and averages 6 feet deep. When the lake supply is exhausted water is pumped into it against an average lift of 20 feet. The river plant consists of one 36-inch centrifugal pump, rope driven by one 24 by 42-inch Corliss engine, which is supplied with steam by tubular boilers. The relift plant at the lake consists of two 24-inch centrifugal pumps, driven by one 18 by 42-inch Corliss simple-condensing engine, and one 22 by 28-inch slide-valve engine. The main canal is 9 miles long, 100 feet wide, with a longitudinal slope of 2.5 feet per mile, and cost $1,250 per mile. It has sufficient capacity to serve 6,000 acres. There are 11 miles of laterals, having a slope of 3 feet per mile, and costing $400 per mile to construct. The cost of maintaining canals and laterals is estimated at $800 per annum.

Water is not measured, the water rent is one-fifth of the crop, and the duration of irrigation period is ninety days. The average depth of water applied is 3 feet and the average rainfall for the last three years is 3 inches during the irrigating season. The area under cultivation in 1908 was 4,160 acres and the probable area for 1909 is estimated at 6,000 acres; the total acreage which can be brought under canal by enlarging the canal and plant is estimated at 12,000. The value of unimproved land in the vicinity is given as $8 per acre before irrigation and $27.50 after irrigation, while the value of irrigated lands is put at $35. The cost of preparing land for irrigation is estimated at $1 per acre. Rice is grown exclusively and is marketed at Eagle Lake and Houston mills, the average cost of producing and marketing being estimated at $27.25 per acre, and the average value of crops at $35; the average yield is 12.5 barrels. About 5,000 acres are now upon the market in 80-acre and 100-acre tracts at $30 to $35, water rights included. Northern grain farmers are the class of settlers preferred. The total acreage to be irrigated in the vicinity in 1909 is estimated at 6,000, while the ultimate acreage will be 25,000.

Wells.—J. W. Leech, of El Campo, Tex., 74 miles west of Houston, on the Victoria division of the Southern Pacific system, writes that there are 125 wells in his immediate vicinity which are used for irrigating, and he estimates the acreage irrigated at 20,000, and room for more. He states that there is a large canal system which is now

being installed at Pierce, which will secure water from the Colorado River. Also that the Kinchloe Irrigation Company at Glenn Flora has a large plant in operation. These are the only systems in that vicinity except small canals from wells. He says that pumps of all makes, mostly operated by gasoline, are used in bringing the water to the surface from the wells, in which the water rises nearly to the ground level.

The following is a list of canal companies in Group I, as far as ascertained. The acreage for 1907 and 1908 is from the "Rice acreage report in Texas," issued by the Texas Rice Farmers' Association, of which A. E. Groves, of Houston, is secretary and treasurer. The last column is from the Southern Pacific Railroad Company's "Rice belt" map, and gives the approximate ultimate acreage which can be served as compiled by Mr. Duller, of Houston.

List of canal companies and acreages.

Name.	Canal number.	Area.		Approximate ultimate area.
		1907.	1908.	
		Acres.	*Acres.*	*Acres.*
Oriental Seed Rice Co	57	.....	.....	3,000
Cow Bayou Canal Co	2	3,000	3,000	15,000
Port Vernox Oil Co	1	.....	.....	7,000
Kechi Rice Co	58	.....	.....	5,000
Des Moines Rice Co.[a]	.....	.....	1,200	.....
Samuel Wilson Canal Co	41	.....	.....	5,000
Giles Bros. Co	42	.....	.....	5,000
Clark Canal Co	40	1,500	1,500	5,000
Adams Bayou Canal Co	39	3,284	3,284	15,000
Orange Company Irrigation Co	62	3,340	3,340	4,000
Port Arthur Irrigation Co	27	7,950	9,000	15,000
McFadden-Weiss-Kyle Canal	4	9,000	15,000	20,000
Neches Canal Co	6	23,000	21,000	.....
Beaumont Irrigation Co	5	17,000	16,000	20,000
Ed Moore	73	.....	.....	1,000
Jefferson County Canal Co	3	.....	.....	20,000
Lowell Bros. Canal	72	.....	.....	1,000
J. C. Ward	77	.....	.....	1,000
J. H. Garland Canal	.....	.....	.....	1,000
J. H. Hoopes	76	.....	.....	1,000
George Gill	74	.....	.....	1,000
Schumacher & Fox	75	.....	.....	1,000
Vitrobe Brothers	68	.....	.....	1,000
Mr. Davis	70	.....	.....	1,000
C. A. Place Canal	67	.....	.....	1,000
Taylors Bayou farm	43	3,000	3,000	5,000
Hillibrandt Bayou Canal	44	.....	.....	5,000
Cameron & McClure	69	.....	.....	1,000
Lone Star Canal	9	10,136	10,237	20,000
Farmers Canal	8	5,400	5,400	25,000
Old River Canal	47	9,646	10,000	10,000
Raywood Canal	7	11,000	.....	30,000
Kentucky Rice Irrigation Co	45	.....	.....	5,000
Trinity River Rice and Irrigation Co	.....	.....	.....	.....
Houston Irrigation Co	37	.....	.....	5,000
San Jacinto Model Rice Farm	46	10,000	8,500	10,000
Crosby Canal Co	10	.....	.....	10,000
Harris Company Land and Irrigation Co	36	.....	.....	5,000
Sheldon Canal Co.[a]	.....	.....	.....	.....
Miller Bros. & Mercom Co	87	2,505	2,505	30,000
Deepwater Canal Co	35	.....	.....	5,000
B. W. Camp	34	2,230	2,250	5,000
W. C. Stockton	79	.....	.....	2,000
S. J. Freeland	78	.....	.....	2,000
Exline Canal	80	.....	.....	800
Fort and Fort	81	.....	.....	600
Oberhelman	53	.....	.....	2,000
Krud Canal	.....	.....	.....	600

[a] U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 71. T. U. Taylor. 1902.

List of canal companies and acreages—Continued.

Name.	Canal number.	Area.		Approximate ultimate area.
		1907.	1908.	
		Acres.	*Acres.*	*Acres.*
Hurd Canal	33	.....	.....	5,000
Herrick & White	85	.....	.....	5,000
J. C. Walker	84	.....	.....	2,000
Jackson Lake Canal	54	.....	.....	3,000
Rodemiller Canal	32	.....	.....	5,000
Angleton	.....	4,260	2,500	.....
Munson Canal Co	.....	.....	.....	.....
Brazoria Irrigation Co	11	.....	.....	30,000
Sugarland Canal	31	.....	.....	5,000
Cane and Rice Belt Irrigation Co	12	.....	.....	75,000
Wallis Canal	13	.....	.....	10,000
Stewart Canal	86	1,528	2,400	3,000
Buckeye Canal Co	49	4,245	.....	5,000
Kloor Canal	66	.....	.....	2,000
Security Canal	23	3,520	3,000	10,000
Tres Palacious Canal	25	4,889	4,889	10,000
Gravity Canal	22	5,660	4,500	25,000
Colorado Canal	21	5,500	5,000	15,000
Northern Canal	24	9,595	9,000	10,000
Matagorda Canal	20	6,090	5,500	10,000
Moore-Curtis Canal	48	7,896	5,250	15,000
Bay City Canal	19	400	.....	15,000
Prairie Bluff Canal	85	.....	.....	2,000
Southern Irrigation Co	18	13,000	8,500	20,000
A. P. Borden Irrigation Co	65	.....	.....	30,000
Glen Flora Canal	68	.....	.....	5,000
Kenchloe Canal	.....	13,500	8,500	.....
Lakeside or Donovant Canal	17	.....	.....	5,000
Garwood Canal	15	1,720	1,720	5,000
Eagle Lake Rice Co	14	3,500	4,000	10,000
Tuttle & Harmon	30	3,535	3,000	10,000
Jackson County Irrigation Co	63	.....	.....	2,000
Gale Plant and Irrigation Co	24	.....	.....	10,000
Red Bluff Canal	29	.....	.....	10,000
Southern Irrigation Co	55	.....	.....	10,000
Saki Farm or Nipon Irrigation Co	26	.....	.....	20,000
Buchel Plant	50	100	.....	10,000
Victoria Rice and Irrigation Co.[a]	.....	5,500	2,500	.....
Rooth Canal	.....	300	300	.....
Osceola Canal	.....	500	.....	.....
Cove Canal	.....	1,200	1,200	.....
Onishi Canal	.....	1,200	1,000	.....
Frost Canal	.....	3,500	8,000	.....
Dheldon	.....	5,000	4,500	.....
Katy district	.....	2,000	2,200	.....
Ganado district	.....	5,500	6,000	.....
Chesterville district	.....	4,680	4,680	.....
Garwood district	.....	1,720	1,720	.....
Mykawa district	.....	2,470	1,260	.....
Palacios district	.....	1,720	1,000	.....
El Campo district	.....	7,900	8,960	.....
Friendswood district	.....	1,720	1,900	.....
Des Moines Canal	.....	.....	1,700	.....
Waterhouse Rice Canal	.....	.....	1,000	.....
Scattering	.....	.....	3,590	.....
Total	.....	257,239	229,925	727,000

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 158, pt. 5.

GROUP II.

The region along the lower coast country from Beeville to Brownsville is included in Group II. Around Beeville and Corpus Christi truck and fruit have been grown for many years, and rice has been tried also in the lower portion of the Coastal Plain, but appears to have proven less profitable than other crops. Only one brief description of an irrigation system at Beeville was secured, the information being furnished by the superintendent of the state

experiment station. For the large systems near Brownsville a few reports have been received direct from some officers of the companies, but the bulk of it was supplied by W. L. Rockwell, of this Office.

The State Experiment Station.—Water is derived from a 6-inch bored well, 174 feet deep. The lift is 60 feet, the water being pumped at the rate of about 60 gallons per minute by means of a 6-horsepower gasoline engine, into a 100,000-gallon earthen reservoir, which is lined with a coat of mastic consisting of 25 parts coal tar, 2 parts lime, and 73 parts sand. Mr. Waschka, the superintendent of the station, estimates that it would cost about $1,400 to build complete a plant of this kind. If the water is properly distributed, 8 to 10 acres can be irrigated. Mr. Waschka writes:

> It is probably better to say that there is no irrigating done in Bee County, except a few small truck patches that are irrigated from wells, water being drawn by gasoline engines and windmills. There are no live streams through this county, but good water is inexhaustible at a depth of about 150 feet.

The surface of the country at the experiment farm, as well as to the north and west of Beeville, is undulating and in the natural state is covered with mesquite and live oak. The soil of the ridges is a red and black sandy loam underlain at a depth of 1 to 4 feet with a rotten limestone rock, into and through which the roots of the trees penetrate. On the lower ground below this cap rock the subsoil is a yellowish, pervious clay 2 to 4 feet below the surface. The soil to the southeast of Beeville consists of a light sandy loam, with a clay subsoil, and the landscape is somewhat more uniform than in the opposite direction. At the experiment station about 4 acres are planted in citrus fruits. Three-year-old Duncan, Royal, and Pernambuco pomelos stand 6 to 7 feet high, and bore in 1908, 400 to 650 fine fruits. Three Villa Franca lemon trees, 8 feet high, bore 1,000 fine merchantable lemons. The Japanese varieties of oranges are making an exceptionally fine showing. With proper care there seems to be little doubt that the hardier varieties of citrus fruits will be a commercial success in this section. By withholding moisture, excepting in proper growing periods, from this naturally well-drained soil, the trees may be rendered sufficiently hardy to withstand the frosts of this region. It is necessary to supply moisture occasionally during the fruiting season, and this can be supplied by wells, from which good water can be obtained at a depth of 100 to 125 feet. As this district lies between the humid and semiarid sections of the State, it receives a more even rainfall during the growing season than portions farther south. The station has experimented also with olives in a number of varieties, all of which are doing well.

Though it is necessary to occasionally supply moisture to fruit trees in order to produce a first-class quality of fruit, it is very seldom that there is not plenty of rainfall to grow fine vegetables. Cabbage,

cauliflower, turnips, beets, radishes, spinach, and lettuce can be grown there during the fall and winter to supply the northern markets.

The Brulay estate.—This farm is situated 8 miles below Brownsville, on the left bank of the Rio Grande, and is equipped with a 10-inch centrifugal pump having 12-inch spiral-riveted suction pipe 500 feet long. This long suction was made necessary because of a change in the channel of the river which left the pumping plant that far away from the bank of the river. The lift varies from 4 to 19 feet, according to the stage of the river. The total area under irrigation is 200 acres, of which 160 acres is in sugar cane and 40 acres in mixed crops. The canal is probably 2 miles long and 2 feet wide on the bottom. The yield of sugar cane is 30 tons to the acre.

The Indiana Cooperative Canal Company.—This system is under construction and will use as a reservoir the Resaca de la Palma, which is 200 feet wide and 15 feet deep and may be filled any time the river rises 7 feet above the normal stage. The pumping plant is on the Rio Grande, about 3.5 miles below Brownsville. The cost of construction of headworks was about $30,000, the cost of pump and engine $6,500, and the cost of setting same $6,000. The capacity of pump is given as 30,000 gallons per minute, and the maximum lift as 10 feet The pump is direct-connected to a 14 by 20 inch automatic engine, which receives steam from a 150-horsepower boiler. The length of the main canal is 25 miles. At the river it is 24 feet wide at the bottom, 11 feet deep, and has side slopes of 2 to 1. Its carrying capacity is 250 cubic feet per second and the cost was $120,000. There are 30 miles of laterals costing $1,000 per mile for construction. The side slopes are 1½ to 1 and the longitudinal slope 18 inches per mile. The cost of maintenance for canals and laterals is not known, but is estimated at $1 per acre. Water will be measured by weirs, using the Reclamation Service tables, and the annual rental will be based on a fixed charge of $1 per acre for the general expenses, and the additional expense for fuel, oil, engineer, etc., will be prorated according to the amount of water used. No profits are figured on, and any unused remainder of the fixed charge will become a sinking fund for the renewal of machinery, etc. The irrigation period will be continuous throughout the year and the amount which will be needed for each acre is estimated at 2 acre-feet per annum. The average rainfall is slightly more than 27 inches, according to the U. S. Weather Bureau records. No acreage was planted during 1908, but 2,000 acres are expected to be under cultivation in 1909. The total acreage which can be served is placed at 25,000, and eventually 37,000 acres in the section east of Brownsville on all canals.

The Piper Texas Plantation Company.—Water is pumped from the Rio Grande, 3 miles below Brownsville, by means of a 6-inch centrifugal rope-driven pump, working against a lift which varies from 10 to

20 feet, according to the stage of the river. There are 6 miles of main canal, 4 feet wide at the bottom, 2 feet deep, and side slopes of 2 to 1, and about 12 miles of laterals 1.5 feet deep. For 1908 the acreage was given as 135 acres in sugar cane, 150 acres in cabbage, 30 acres in melons, 200 acres in corn, and 25 acres in potatoes. The estimated total area for 1909 is 800 acres.

The Kirby Plantation.—This farm is located about a mile below Brownsville and draws water from the Rio Grande by means of a 10-inch centrifugal pump with a lift varying from 6 to 18 feet, according to the stage of the river, the capacity of the pump being 5,000 gallons per minute. The cost of pump and engine installed was about $800.

For 1908 there were 134 acres and for 1909 there will be probably about 260 acres under cultivation. The crops grown are corn, melons, cabbage, potatoes, beans, and sorghum.

The Brownsville Irrigation Company.—Water is pumped into the canal from the Rio Grande at Brownsville against an average head of 7.5 feet by a 36-inch and two 24-inch centrifugal pumps, rope-driven by two 100-horsepower slide-valve engines and one 225-horsepower Corliss engine, steam being furnished by two 125-horsepower tubular boilers and one 260-horsepower water-tube boiler. The combined capacity of the pumps is stated as 100,000 gallons per minute. The fuel used is mesquite wood. The total first cost of plant is estimated at $40,000 and the estimated annual cost of maintenance at $10,000.

There are 35 miles of main canal and larger main laterals varying in width from 120 to 30 feet and having a fall of 1.5 feet per mile. The first cost was about $85,000. The annual cost of maintaining canals and laterals is stated as about $11,000. The water furnished is not measured, but is furnished on a flat rate of $4 per acre per annum for corn and cotton, $6 for sorghum, sugar cane, and alfalfa, and $10 for truck. The irrigation season lasts practically all the year and the amount of water required depends upon the crop. For corn and cotton it is estimated as being equivalent to a depth of 12 inches, while for sugar cane it is given as 28 inches. According to the report of the U. S. Weather Bureau, covering a period of 35 years, the average rainfall during the cotton-growing season was slightly in excess of 7 inches.

For 1908 there were 4,500 acres under canal and for 1909 the acreage will be probably 5,000, while the ultimate area that can be brought under the canal will be about 30,000 acres. Before irrigation, lands in the county were worth about $1 per acre, unimproved. They are worth now $40 to $100 and irrigated lands from $60 to $150 per acre.

Average cost and value per acre of crops, and number of acres one man can tend.

Crop.	Average cost of producing and marketing.	Average value per acre.	Area one man can tend.[a]
			Acres.
Corn	$16.50	$27.50	50
Cotton	22.00	45.00	50
Sorghum	20.00	40.00	70
Alfalfa	23.50	75.00	60
Sugar cane	79.50	160.00	40
Onions[b]	140.00	350.00	.....
Cabbage	40.00	200.00	10
Celery	800.00	1,500.00	5
Truck	100.00–150.00	300.00–400.00	5

[a] Extra help often required at harvest time.
[b] If fertilization is needed add $20 to $50 to cost of production.

The average funds and equipment needed are listed as 1 team, $300; wagon, $75; cultivator, $40; harrow, $15; disk plow, $75; mower, $50; rake, $25; garden tools, $150; and $500 in money. There is plenty of room for more settlers, the estimated number being given as 2,500 farmers. The probable acreage irrigated in the vicinity for 1909 is 5,000 and the ultimate acreage 30,000.

The San Benito Land and Water Company.—This plant takes water directly from the Rio Grande and has reinforced concrete head works from the flow line to the bottom of the river which, with eight gates, cost $45,000. The cost of maintenance of head works is said to have been $2,000 in 1908. There is one 78-inch propeller pump and one 24-inch centrifugal; the combined capacity of the pumps is 100,000 gallons per minute against a 10-foot lift. Power is furnished by a slide-valve engine and tubular boilers. The cost of the pumping plant was $12,000 and the cost of maintenance in 1908 until about July 15 was $1,900. The total cost of construction, including the lateral system, is given as $250,000. There are 27.5 miles of main canal, mostly a natural waterway, and the slope is 1 foot to 8,000 feet. The carrying capacity is placed at 575 cubic feet per second and the cost of canal construction at $95,000. There are 34 miles of laterals having a fall of 2.5 feet in 5,000 feet, and their cost was about $90,000. The cost of maintaining canals and laterals from January 1 to July 15, 1908, was about $2,000. Water is sold at a flat rate of $4 per acre for cotton and $6 for sugar cane and alfalfa. Irrigation continues all the year round, and the average amount of moisture necessary to apply is 20 inches, the rainfall being given as 24 inches—the Weather Bureau records show the average to be 27 inches at Brownsville.

During 1908 there were only 2,000 acres under cultivation, the system being in process of construction, but it is expected that 10,000 acres will be planted in 1909, while the ultimate area which can be brought under canal is estimated at 50,000 acres, of which this company owns 36,000. The value of unimproved lands before the

irrigation system was installed was $3 per acre; after irrigation it was increased to about $50 per acre, while the irrigated lands are valued at $75 to $250. The principal crops and their average yields are given in the following table:

Average yield, cost, value, and net returns of crops, and number of acres one man can tend.

Crops.	Yield per acre.	Average cost per acre.	Average value per acre.	Average net returns per acre.	Acreage one man can tend.[a]
					Acres.
Cotton	1 bale	$22.00	$45.00	$23.00	50
Corn	50 bushels	16.50	37.50	21.00	50
Alfalfa	6 tons	23.50	75.00	51.50	60
Sugar cane	40 tons	80.00	160.00	80.00	40
Onions	22,000 pounds	120.00	350.00	210.00	5

[a] Extra help needed in harvesting.

The equipment and funds needed for one man should consist of one team of mules and harness ($300), wagon, plow, mower, rake, harrow, garden tools, and about $500 in money. Many men succeed without anything to begin with if they can secure advances from merchants or landowners. The opportunities for settlement are good and the probable number who can be accommodated is placed at 13,000. Honest, hard-working Americans, Swedes, Germans, or Bohemians are welcome.

The Harlingen Land and Water Company.—Water is pumped from the Rio Grande at Harlingen, 19 miles above Brownsville, by means of a 24-inch and two 36-inch centrifugal pumps run by one 125-horsepower and two 275-horsepower engines. This plant is in process of construction and the cost data are not available. The main canal is 22 miles long, 30 feet wide on the bottom, and side slopes 2 to 1. The average depth is 5 feet and the grade 1.5 feet per mile. There are approximately 50 miles of laterals having 6-foot bottoms, 2 to 1 side slopes, and a depth of 3 feet. The soil is rich, sandy silt, containing a large percentage of vegetable matter. The available acreage is about 40,000, and the land subject to irrigation is valued at $50 to $65. The water rental will be $10 per acre for truck, $6 for sugar cane, alfalfa, and sorghum, and $4 for cotton and corn. These water rates are based on one crop per season, but if a second crop of other products is raised the additional charge is one-half the original charge. The same crops as under the San Benito system may be grown with equal net returns. There were about 200 acres in sugar cane, sorghum, corn, and cotton in 1908, and there will probably be 2,000 in 1909. It is the intention of the owners to increase the acreage in sugar cane and erect a sugar mill.

La Gloria Canal Company.—The system now under construction by this company will pump water from the Rio Grande at Santa Maria by means of an 18-inch centrifugal pump. There are 5.5 miles

of main canal, 20 feet wide at the bottom and 2 to 1 side slopes, and a water depth of 3 feet. For the first mile the grade is 3.5 feet and beyond that 2 feet per mile. Four and one-half miles of laterals are built and there will probably be 20 miles of these. The side slopes are 2 to 1 and the depth about 2 feet. The company owns 1,700 acres, but there are about 2,700 acres additional west of the canal, which can be served by it.

The Santa Maria Irrigation Company.—This is the oldest irrigation system on the river, with the exception of the Brownsville Irrigation Company and the Brulay estate. Water is pumped from the river by means of an 18-inch centrifugal pump run by a 75-horsepower engine and 100-horsepower boiler. An additional 24-inch centrifugal pump was installed during the fall of 1908. The main canal is 4.5 miles long and the width of the canal proper is 10 feet on the bottom, with approximately 4 to 1 side slopes and 3.5 feet deep. Of this, 2 miles have a longitudinal slope of 0.55 foot per mile, the remainder having a fall of 2 feet per mile. There are 7.5 miles of laterals. There were under cultivation in 1908, 4,000 acres in beans, onions, cabbage, and other truck, including 5 acres of celery, which brought a net return of $700 per acre. The land under this section is particularly well adapted to truck growing.

The American Rio Grande Land and Irrigation Company.—This will be the largest system on the river when it is completed. Water is pumped from the Rio Grande into an old channel which has been utilized as a reservoir and which has an area of 560 acres and a capacity of 3,000 acre-feet. An emergency canal 2 miles long leads around this reservoir into the main canals. Two 36-inch centrifugal pumps, operated by a 250-horsepower 3-phase motor, and having a capacity of 28,000 to 34,000 gallons per minute, depending upon the stage of the river, have been installed and operate against a head varying from 4 to 24 feet. Floor space is available for a 48-inch centrifugal pump which will be installed later. The power house is located at Mercedes, 6 miles from the pumping station. It is equipped with steam turbines and electric generators and cost $70,000. The fuel used is crude oil. There are 18.5 miles of main canal and 50 miles of laterals, the cost of both being $490,000. The cost of maintenance is not yet determined. The emergency canal has a cross section of 400 square feet at low-water level in canal and is 2 miles long. The north trunk canal is over 100 feet wide, but no data regarding the east trunk are available. Water will be charged for at the rate of $1 per acre per irrigation, but nothing is said as to the quantity which may be used at one time. The irrigation period lasts the year round. There were 1,000 acres in cultivation in 1908 and there will be probably 5,000 in 1909, and ultimately 100,000 acres will be served. Before this plant was constructed the lands were valued at $7 per

acre; unimproved lands sell now for $50 to $100 per acre, and irrigated lands for $75 to $150. The crops which may be cultivated are stated to be "everything that grows." It is estimated that 3,000 families can be accommodated on this canal alone.

The total outlay on this plant, including power and pumping machinery and canal system, will be $1,000,000.

Withers Canal.—This canal is being installed 3 miles above Mercedes, at Llano Grande. There is one 24-inch centrifugal pump, which lifts water from the Rio Grande, and the cost of the pumping plant was $11,000. The main canal is 20 feet wide on the bottom, side slopes 2 to 1, and a depth of 5 feet. The water slope is 1.5 feet per mile, and there are 4.5 miles completed, which will be extended to perhaps 15 miles. There are now 200 acres in truck, 3 acres in Satsuma oranges, and 2 acres in olives. Ultimately, upward of 10,000 acres can be served by this system.

The La Blanca Agricultural Company.—This company is located at Donna, Tex. Its president was unable to furnish the desired data, but states that he came to that region in 1902, when lands were worth $1.25 per acre. His company was organized and began experimenting upon the products which could be grown under irrigation, notwithstanding there were then no railroads to furnish facilities for marketing. A small pumping plant was installed and about 400 acres were irrigated, but no cost data were kept. Now lands under the company's canals are worth from $50 to $80 per acre, but land which can not be brought under irrigation is scarcely salable at any price. The crops during the past winter and spring averaged 500 bushels of onions per acre, 200 to 500 bushels of cucumbers, a heavy crop of alfalfa, and 40 to 60 bushels of corn. Two crops of corn can be grown in a year. Sugar cane is estimated to yield 40 to 60 tons per acre. Not less than 160 carloads of truck were shipped from Donna station during the spring of 1908. A very large irrigating plant is being installed on the lands of the company, which will reach out 18 miles from the river and will serve 25,000 acres.

La Donna Canal Company.—The maximum lift from the Rio Grande is 14 feet, at Donna, Hidalgo County, where this system is being installed. There are two 30-inch pumps, direct-connected to two 150-horsepower compound condensing engines. Two 150-horsepower water-tube boilers furnish steam. When completed there will be 18 miles of canals. The number of acres in cultivation in 1908 was 1,000; the probable number for 1909 will be 3,000, and the ultimate number to be reached by canal will be 17,000. The present value of unimproved lands is put at $50 per acre and of irrigated lands $100 to $150 per acre. The average cost of preparing the land for irrigation is $25 per acre. The crops to be grown will be sugar cane, alfalfa, corn, and all kinds of truck, onions being a specialty. For 1908 the aver-

age yields are given as follows: Onions, 450 bushels; cucumbers, 200 bushels; corn, 40 to 50 bushels. The products are marketed in Denver, Minneapolis, the East, and the South. Probably 300 settlers can be accommodated on the canal system.

Closner canals.—On the Closner ranch, near Hidalgo, there is an 18-inch centrifugal pump installed, with which water is lifted from the Rio Grande to irrigate 150 acres of alfalfa and 600 acres of sugar cane. Mr. Closner has taken considerable care in the preparation of his land for alfalfa and has produced hay of excellent quality. His fields yield upward of 6 tons per season and his hay sells at an average of $12 per ton. The sugar cane yields 40 tons, or 3 tons of sugar per acre, worth $180 to $200. Sold in large tracts in the wild state lands bring $20 per acre. Under a canal system the prices range from $40 to $60 per acre; under irrigated cultivation the value varies from $75 to $150 per acre.

The Hidalgo Canal Company.—There are two lifts on this canal, the second being 6 miles back from the river. The first lift, at McAllen, has two 24-inch centrifugal pumps, which raise the water 6 to 18 feet, according to the stage of the river, and at the second lift there is a 15-inch and another 24-inch centrifugal pump, which raise the water an additional 26 feet. The capacity of the pumps at the first lift is 36,000 gallons per minute, and at the second lift 27,000 gallons per minute. Eight thousand acres are irrigated from the first lift, and eventually 18,000 acres will be irrigated by the canal system. The crops now grown are alfalfa, Egyptian corn, sorghum, and truck, but grapes, peaches, apricots, and other fruits will be cultivated on the second bench land.

The Rio Bravo Irrigation Company.—The intake of this canal system is located 600 feet above the intake of the Hidalgo Canal, where there is a 24-inch centrifugal pump of 20,000 gallons capacity per minute. The lift varies from nothing to 20 feet, according to the stage of the river. The cost of the pumping plant was $4,000. The main canal is 30 feet wide at the bottom, has side slopes of 2 to 1, and falls 1 foot in 4,000 feet. The company owns 4,000 acres, but lands adjacent, to the extent of 12,000 acres, can be served by the canal when completed. The entire cost of the system will be $40,000. Land will be sold to farmers direct at $50 per acre, including one $10 share of stock in the company for each acre purchased for a permanent water right, the purchaser to pay for water for entire acreage bought at the rate of $2 per annum from the time water is ready to be delivered to the land.

La Lometa Canal Company.—This system is situated at Mission, Hidalgo County, and is in process of construction. Water will be lifted 18 to 28 feet from the Rio Grande by means of centrifugal pumps, of which there are two now in operation, having a combined

capacity of 40,000 gallons per minute. The cost of construction was $18,000. Four miles of main canal is completed, which will be extended. It is built so that increased capacity can be added as required. There are 7 miles of laterals completed and more under construction. The general slope is 1 foot per mile. There has already been expended $100,000. The system of measuring water to farmers has not yet been installed, but the system of "miner's inches" will be used. The rate of water rental is put at $1 per watering, and it is expected that 24 to 30 inches depth will be needed during a season. Five hundred acres were under cultivation during 1908 and it is expected to cultivate 2,000 to 5,000 acres during 1909. The area which can be brought under canal ultimately is stated at 20,000 acres. Unimproved lands in the vicinity before irrigating are valued at $20 per acre. The present selling price of lands under irrigation is $50 to $150 per acre. The cost of preparing land for irrigation is $25 per acre and the crops raised are winter vegetables, alfalfa, sorghum, cane for fodder, cotton, sugar cane, citrus fruits, figs, and dates, and a few bananas. The average value of crops is placed at $25 to $300 per acre, but the average net return has not yet been determined. Land can be bought for one-fourth cash payment, balance in one, two, and three years, with interest at 6 per cent. One man can care for 5 to 75 acres, depending upon the character of the crop, and it is estimated that there are 500,000 acres capable of cultivation on the Texas side of the Rio Grande delta. Settlers should have at least $2,000 cash when making a start.

W. S. Dougherty Canal.—Three miles above Mission there is a small irrigation system belonging to the estate of W. S. Dougherty. A 12-inch centrifugal pump raises water from the Rio Grande against a maximum lift of 20 feet, and has a capacity of 8,000 gallons per minute. The main canal, 1 mile long, has a width of 6 feet at the bottom, a depth of 4 feet, and side slopes of 2 to 1. There are 10,000 acres in this ranch, but only 140 acres were irrigated in 1909, of which 108 acres were in Bermuda onions and 32 acres in alfalfa and corn.

As far as could be learned, the above descriptions cover all the irrigation systems now in operation or under construction on the lower Rio Grande, but within the area classed as Group II are other canal systems concerning which no data were available. However, the following data were obtained regarding a single small plant irrigated from a well.

Thompson Garden.—A. C. Thompson and W. C. Thompson have 12 acres in general garden truck 1.5 miles west of Falfurrias, which they irrigate from an artesian well. The flow of the well has been increased by placing a centrifugal pump 17 feet below the surface, the pump being run by an 8-horsepower gasoline engine. One hundred and eight gallons per minute are delivered and this is supposed to be the

capacity of the well. It is expected to install a windmill soon which will pump water from the well into a small reservoir which is now in place at the well, and into another which will be constructed 800 feet distant. The well is 605 feet deep, lined with 5-inch casing, three-sixteenth-inch thick, down to the clay stratum which overlies the one in which water is found. In this latter stratum the casing is 4.25 inches in diameter and 20 feet of it is pierced by 1,600 half-inch holes. The growing season continues the year round, but not much water is necessary in the winter. The gardens are just being put into shape and only 12 acres are now under cultivation, which will be increased to 15 acres in 1909. Unimproved lands are valued at $100 per acre and it costs $30 per acre to bring them under irrigation. There is plenty of good land for sale at $20 to $100 per acre from 1 to 5 miles from the railroad, and there is room for 500 settlers, who should be energetic and persistent, having $2,000 to $5,000 to invest. Mr. Thompson, who furnished the above information, estimates that 10 per cent of the land in that section is irrigable. Below is given a list of well systems compiled from existing data, but as this is 4 to 6 years old the list does not begin to represent conditions as they exist now. The table embraces those systems in Group II for which data were obtainable.[a]

Irrigation systems in Group II.

Name of company.	Locality	Source of water.	How introduced into canal.	Cost exclusive of land.	Area cultivated.	Crops raised.
					Acres.	
Rankin farm	Beeville	3 wells	Pump		20	Truck.
Messenger farm	do	1 well	do	$750.00	10	Do.
Stovall farm	do	do	do	425.00	(a)	Corn, beets, truck.
Eidson farm	do	do	do	800.00	1	
Muckelroy farm	do	do	do	476.45		
Grissett place	do	2 wells	do		2	Truck.
McDowell farm	do	do	do		4	Do.
Koon place	do	1 well	do		5	Do.
Bowen farm	do	do	do			Do.
Mock farm	do	do	do			Do.
Elliott farm	do	2 wells	do		5	Do.
Huff farm	Corpus Christi		do		35	Do.
Kleberg farm	do		do		15	Do.
Trott farm	do	Well	Pipe line		8	Do.
Everhardt farm	do	Rain and well	Pump		7	Do.
Heath farm	do	Well	Windmill		(a)	Do.
Knox farm	do	do	do		4	Do.
Kenedy ranch		8 wells				
Armstrong ranch		19 wells				
El Sauz ranch		4 wells				

[a] Small tract.

GROUP III.

Group III includes the territory lying in the vicinity of San Marcos, New Braunfels, San Antonio, Seguin, Eagle Pass, and Del Rio, together with the intervening territory, and while there are many comparatively small irrigation systems in this group, water

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 158, pt. 6.

for which is derived from both streams and wells, little first-hand information could be secured. However, it is probable that the tabular data given after the few detailed descriptions which were obtainable more nearly represents conditions as they now exist than would be the case for either Groups I or II, because there has been less recent development in this area, except for the portion lying along the Rio Grande at Laredo, Eagle Pass, and possibly Del Rio. Irrigation on the systems of this group is devoted chiefly to the raising of garden truck and staple products

Collins garden.—Three miles west of San Antonio F. F. Collins irrigates 172 acres from a 12-inch artesian well, 700 feet deep, the natural flow of the well being relied upon entirely for the supply, which Mr. Collins states would furnish water enough for 400 acres if the flow were conserved in a reservoir of sufficient size. The land has a fall of 10 feet to the mile east and 8 feet to the mile south. The laterals run north and south from the main canal every 300 feet. Each lateral is 1,150 feet long (the width of the tract, which is about a mile long) and about twelve rows, running east and west, are watered at a time. The well cost $4,500, but the canal and laterals were constructed very cheaply and the cost could not be approximated. The flow of the well is applied to each acre about one day in every seven, and the rental is $15 per acre for water, house, and barn, and $5 per acre for the land. The estimated amount applied per acre per annum is 2 acre-feet. The tract owned by Mr. Collins cost $50 per acre in 1900 and the price was then considered high. Recently $200 per acre has been paid for land near by. The land is divided into 12-acre tracts and the cost of a house and barn and hydrant water for each tract was about $1,000. Mr. Collins has refused $500 per acre for his farm.

Data on the cost of producing and marketing various vegetables were not obtainable, but it is stated that some renters clear as much as $200 per acre while others make little or nothing. One man with help can care for 12 acres and each beginner should have $1,000. The entire tract of 172 acres was irrigated in 1908 and the same will be done in 1909. In the vicinity it is estimated that 2,000 acres will be under irrigation in 1909 and 20,000 acres or more are available for irrigation in that section. For market gardening Belgians are preferred and Germans next. Mr. Collins, who furnished the information, states that the artesian belt is limited, but that by conserving the flow in reservoirs a large scope of country can be irrigated. He states that the slope of the land is so uniform that there is no difficulty in preparing it for irrigation.

The Schriever and Half System.—This irrigation system is situated 4 miles west of Pearsall. The source of the water used is a 6-inch artesian well, 1,450 feet deep, which discharges 400 gallons per

minute into an earthen reservoir 200 feet square, built up 8 feet above ground. The reservoir is situated in the center of the irrigated area, and from it the water is distributed over the ground in small plowed ditches. The total cost of boring the well, including casing, was $6,000, and the cost of building the reservoir was $500. The cost of maintaining reservoir and ditches is practically nothing. The rental for both land and water is one-third the gross production, and the area cultivated in 1908 was 200 acres. For 1909 the same area will probably be irrigated. Unimproved lands before irrigating were valued at $8 to $10 per acre, and the cost of clearing and breaking at $2 to $5 per acre, but this does not include any part of the cost of the irrigation plant. Irrigated lands are valued at $50 per acre. The crops and yields are as follows: Onions, 20,000 pounds per acre; cabbage, 1,600 pounds; sweet potatoes, 300 bushels; watermelons, 1 carload. These are marketed in Pearsall.

The Comanche Ditch Company.—This is a chartered stock company with a capital stock of $25,000, with an office at Batesville, Zavalla County. A timber and mud dam across the Leona River constructed thirty years ago serves to divert the water on the right bank at a point about 2.5 miles above Batesville. The landowners constitute the stockholders, each acre being considered one share. Assessments are levied from time to time to maintain ditches and rebuild the dam when demolished by floods. The main canal is about 2.5 miles long, 4 feet wide, and in places is 6 or 7 feet deep. The irrigation period continues seven months, and no attempt is made to measure the water applied to the land, the only rental being the variable assessment levied in order to keep ditches and dam in repair. In 1908, 500 acres were irrigated, and the same acreage will be irrigated in 1909, though it is estimated that nearly 1,500 acres can be brought under canal. Unimproved lands before irrigating were valued at $1 per acre, and the present value of unimproved land in the vicinity is $4 per acre. It costs $8 per acre to bring the land under irrigation, after which it is valued at $35. The crops grown are Johnson-grass hay, corn, cotton, onions, garden truck, and peaches. The products are marketed in Uvalde. The cost of production and marketing depends upon the crop grown. To produce a crop of onions costs $150 to $175 per acre, with a gross return of $300 to $350. To produce a year's growth of Johnson-grass hay will cost $12 to $15, and the gross returns will be $30 to $35. The opportunities for settlement are good, there being room for 75 families in the vicinity. Quite an acreage in the Leona Valley can be irrigated by pumping from the stream and from wells.

Las Islitas Irrigation Company.—This company is located near Islitas, about 15 miles above Laredo. Water is pumped from the Rio Grande against a 57-foot lift by a 10-inch centrifugal pump hav-

ing a capacity of 4,000 gallons per minute. The cost of pumping station was $6,000, and the maintenance and operating expenses are $10 per day. There are 2.5 miles of canal, costing $500 per mile, the slope of which is 1 in 600. There are 10 miles of laterals, having the same slope as the canal and costing $50 per mile. The cost of maintenance of canals and laterals for 1907 was $400. The water applied to crops is not measured, but is charged for at the rate of $1 per acre for each time a crop is irrigated. The irrigation period extends from June to April, and the average depth of water applied is estimated at 5 feet—very much in excess of what is necessary. There were 300 acres in cultivation in 1908, and 400 acres will probably be put in cultivation in 1909. By sufficiently increasing the pumping capacity of this system 1,200 acres can be reached.

Unimproved lands before irrigation began were worth $10 per acre, afterwards $30. It costs $15 an acre to prepare the land for irrigating, and the value of irrigated lands is placed at $150 per acre. The crops grown are alfalfa, onions, and cabbage. These are marketed all over the United States and in Canada.

Average cost, value, and net returns of crops and area one man can tend.

Crop.	Average cost per acre of producing and marketing.	Average value per acre.	Average net returns per acre.	Area one man can tend.
				Acres.
Cabbage	$25	$75	$50	20
Onions	150	300	150	10–15
Alfalfa	[a] 4	40	24	60

[a] Per cutting.

If land is leased, $2,000 will be needed to make a start and run one year for 25 acres. The opportunities for settlement are good, and probably 100 intelligent farmers could be placed. The probable number of acres to be irrigated in the vicinity in 1909 is 600, and 4,000 can ultimately be brought under irrigation.

Laredo is the center of a large irrigated area devoted chiefly to onion raising, particularly red and white Bermudas. No detailed information representing conditions at this date could be obtained. There were 1,197 acres of onions in this vicinity in 1908, in tracts of 1 to 44 acres.

The following list is taken from U. S. Geological Survey, Water-Supply and Irrigation Paper No. 71, and from U. S. Department of Agriculture, Office Experiment Stations Bulletin 158, part 6. It covers those systems in Group III, for which data were thus obtainable.

Company or owner.	Locality.	Source of water.	How introduced into canal.	Lift in feet.	Cost, excluding cost of lands.	Acres cultivated.	Crops raised.
Freeman systems [a]	San Marcos	San Marcos River	Centrifugal pump	26		120	Truck.
Do. [a]	do	do	do	26	$675	10	Do.
Glover system [a]	do	do	do	35		100	Alfalfa.
Lowman system [a]	Staples	do	Undershot water wheel	21		3	Truck.
Jones system [a]	San Marcos	do	Centrifugal pump	31	600	20	Corn and alfalfa.
Landa system [a]	New Braunfels	Comal River	Pumps			70	
Locke system [a]	do	do	do	41		33	Orchards, nurseries, corn, etc.
Lenzen system [a]	do	do	do	60		60	Peas, sorghum, corn, potatoes.
Fischer system [a]	do	Guadalupe River	do	60		50	Corn, grass, gardens.
Breummen system [a]	do	do	do	51		18	
Starty system [a]	do	Well	do	20		8	Cane, corn, cotton.
Dittmar system [a]	do	Guadalupe River	do	40			
Ballard plant [b]	Floresville	San Antonio River	do	47		150	Onions.
Spencer plant [b]	Falls City	do	do	50		15	Corn, onions.
McCay plant [b]	do	do	do	37		26	Do.
Weir plant [b]	Karnes City	do	do	47		110	Corn.
San Pedro ditch [a]	San Antonio	Springs	Ditch			500	
San Juan ditch [a]	do	San Antonio River	do			450	
Espado ditch [a]	do	do	Dam and ditch		3,000		
Kampomay system [a]	do	3 artesian wells	Flows			200	Cane, Johnson grass.
Collins system [a]	do	1 artesian well	do			140	
Brady system [a]	do	do	do			50	
Koelblen system [a]	do	do	do		4,000	21	Truck.
Sewerage farm [a]	do	Sewer system	Pipe line			500	
Comanche Ditch and Irrigating Co. [b]	Batesville	Leona River	Ditch			500	Cotton, corn, oats, grass, and truck.
Alexander farm [a]	Laredo	Rio Grande		65		40	Onions.
Madigal farm [b]	do	do		65		13	Onions, truck.
Nye farm [b]	do	do		65		25	Onions, grapes.
Johnson farm [b]				53		4½	Onions.
Matteson farm [b]	Laredo	Rio Grande	Pump	53		15	Do.
Cogley farm [b]	do	do	do	62		8	Do.
Harrey & Thompson [b]	do	do	do	60		20	Do.
Rio Grande Valley Irrigation Co. [b]	Eagle Pass	do	do	46		300	Cotton, cane, melons, corn, pepper.
Pioneer Rio Grande Irrigation Co. [b]	do	do	do	36		350	Onions, corn, truck, alfalfa.
A. B. Frank ranch [b]	do	do	do	52	20,000	250	Alfalfa.
Fern Lake Ranch Co. [b]	Montell	Nueces River	Dam and ditch			190	Corn, cotton.
Jones ranch [b]	do	do	Pump	27		50	Corn, sorghum.
Baylor ranch [b]	do	do	Dam			25	Johnson grass, cane.

[a] U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 71.

[b] U. S. Dept. Agr., Office Expt. Stas. Bul. 158, pt. 6.

Irrigation systems, Group III—Continued.

Company or owner.	Locality.	Source of water.	How introduced into canal.	Lift in feet.	Cost, excluding cost of lands.	Acres cultivated.	Crops raised.
Hargus plant[a]	Cotulla	Nueces River	Pump	36		130	Onions, alfalfa.
Coley plant[a]	do	do	do	40		40	Onions, truck.
Fuller plant[a]	do	do	Pulsometer	35		15	Do.
Goldtrap farm[a]	do	do	Pump	40		101	Cotton, corn, cane.
Gates farm[a]	do	do	do	42½		100	Do.
Seefeld farm[a]	do	do	do	35			Onions, melons, peas.
Kech plant[a]	do	do	do	36		25	Onions.
Taylor plant[a]	do	do	Pump and gravity			175	Onions, corn, cane.
Maney farm[a]	Pearsall	2 wells	Pump	75		9	Onions.
Harkness farm[a]	do	1 well	do	70		4	Do.
Hess farm[a]	do	do	do	75–85		6	Do.
Patterson farm[a]	do	do	do	160		8½	Do.
Trickey farm[a]	do	2 wells	do	60		23	Onions, watermelons.
Berry farm[a]	do	1 well	do	60		7	Onions.
Bennett farm[a]	do	2 wells	do	60		10	Do.
Coker farm[a]	do	1 well	do	110		16	Do.
Little farm[a]	Carrizo Springs	1 artesian well	Flows			16½	Do.
Hughes farm[a]	do	3 artesian wells	do			100	Cotton, corn, and sorghum.
Arnold farm[a]	do	1 artesian well	do			7	Corn.
Shipp farm[a]	do	2 artesian wells	do			30	
Knight farm[a]	do	1 artesian well	do			27	Cotton and grain.
Richardson ranch[a]	do	2 artesian wells	do			400	Corn and truck.
Pollard farm[a]	do	1 artesian well	do			38	Potatoes and truck.
Burton farm[a]	do	do	do			38	Truck.
Jeffrey & Calvan[a]	do	do	do			40	Onions and peas.
Foster place[a]	do	2 artesian wells	do			12	Onions.
Moehrig place[a]	do	do	do			12	Onions and corn.
Owen farm[a]	do	do	do			30	Cotton, corn, cane, and truck.
Kendall place[a]	do	1 artesian well	do			20	Onions and corn.
Oden farm[a]	do	do	do			15	Cotton, corn, cane, and truck.
English farm[a]	do	2 artesian wells	do			48	Broom corn, cotton, and truck.

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 158, pt. 6.

GROUP IV.

No recent data regarding the area embraced in Group IV have been obtainable. The following brief description is taken from an earlier bulletin of this Office.[a]

Holliday Creek system.—This system was constructed during the spring of 1901 by J. A. Kemp, of Wichita Falls, who is one of the owners. An earthen dam, about 0.5 miles long and perhaps 25 feet high at the deepest point, served to hold back water covering about 1,500 acres to a depth sufficient for about 13,000 acre-feet. It was expected to irrigate 4,000 or 5,000 acres below the dam, the water being admitted to the main canal by means of iron gate valves set in two cast-iron pipes which pass through the dam, the pipes having concrete collars at the joints to prevent water from following along the outside of the pipes. This dam was exceptionally well constructed, but because of prairie-dog holes, which were not discovered during construction, a portion of the dam was carried away on May 18, 1901. This was rebuilt afterwards and the water conserved by the dam has since been used for irrigation. Use is made of it also for supplying the waterworks system of the town of Wichita Falls. How successful the enterprise has proven can not be stated, nor can it be stated what the character of crops grown may be, nor the amounts and values of same. The dam and lake were more or less experimental, with a view of proving whether or not a much larger system could be made profitable. It was proposed to locate this larger system on the Wichita River, at a point perhaps 40 miles above the town, the water to be impounded by means of an earthen dam 100 feet high, and the lake to have a storage capacity of 200,000 acre-feet. It was proposed to irrigate lands on both sides of the river, down to its junction with the Red River. As several counties would have to be crossed, and as there was no statute in force at that time which would cover the formation of such an irrigation district, a constitutional amendment was proposed to admit of this being accomplished in this particular case. This amendment was submitted to popular vote, but failed to carry, with the result that the system still remains a mere project. Still another system having a dam and reservoir on the Brazos River was proposed at one time, the object being to lead the water through a low portion of the divide between the Brazos and the Wichita drainage areas and to irrigate a large acreage on the latter drainage. This failed to materialize also, but both these systems seem feasible, provided the problem of silt, as it may affect the storage capacities of the lakes, can be properly dealt with.

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 119, pt. 4.

GROUP V.

The areas in the vicinity of Junction, Menardville, San Saba, Lampasas, San Angelo, Abilene, and other towns are embraced in Group V, but detailed descriptions of only a few of the irrigated farms could be secured.

The Moore farm.—This farm is situated 2.5 miles east of San Saba and is owned by S. M. Moore and managed by J. H. Moore. Water is pumped from the San Saba River by means of a 6-inch centrifugal pump run by a 20-horsepower gasoline engine, against a 30-foot lift. The cost of construction was $1,200 and the cost of running the engine $3.75 for ten hours. Gasoline cost 14.5 cents per gallon in 1908. The canal is three-fourths mile long over nearly level ground. The cost of construction was very small, being estimated at $150, and the annual cost of maintenance the same amount during the irrigating season, the maintenance consisting of cleaning out grass and weeds. The irrigation season is six months. Ninety acres were in cultivation in 1908, probably 115 in 1909, and eventually there will be 150 acres on this canal. Unimproved lands in the vicinity are worth $25 per acre, while irrigated land is worth $60. It costs $10 per acre to prepare the land for irrigation and the crops grown are corn, cotton, potatoes, onions, watermelons, and tomatoes. These are marketed in San Saba and surrounding towns. Corn produces 60 bushels per acre at a cost of $15; cotton, 1 bale, at a cost of $27; potatoes, 200 bushels, at a cost of $40 per acre. The corn is valued at $30, cotton at $40, and potatoes at $200, leaving profits of $15, $18, and $160. One man can manage 40 acres of corn, 30 acres of cotton, and 10 acres of potatoes, and the cost of the outfit for 100 acres is estimated at $500. Opportunities are good for American and German settlers; it is estimated that 15,000 acres can be irrigated in this vicinity.

Thomas Hawkins's farm.—Mr. Hawkins pumps water from the San Saba River, 7 miles west of San Saba, against a lift of 32 feet, by means of a 6-inch centrifugal pump operated by a 12-horsepower gasoline engine. Four to 6 acres can be irrigated per day, the cultivated land being favorably situated for the purpose and lying quite close to the pump. Corn was watered twice during the season of 1908, 25 acres of corn yielding 60 bushels to the acre. It was estimated that 30 acres of irrigated cotton yielded 1 to 1.5 bales per acre. The cotton received two waterings also during the season. On unirrigated cotton lands it was estimated that the yield would be 0.50 to 0.25 bale per acre. The pumping plant was installed in February, 1903, at a cost of $900. The cost of the gasoline was considered the only maintenance charge, as the farmers do all the work themselves. It was estimated that gasoline at 14.5 cents per gallon during 1908 would amount to 45 cents an acre, as against 70 cents during 1907.

Mr. Hawkins does not consider that trucking will pay in that section, because of the distance from market and the scarcity of labor.

Miller Brothers farm.—At Lampasas, water from Sulphur Creek and from a well is utilized to irrigate about 40 acres. There is a 6-inch centrifugal pump located on the creek and 1,000 gallons per minute are pumped against a lift of 25 feet. In the well, on the creek 1,000 yards from the pump, a 5-inch centrifugal pump is installed, which lifts the water 35 feet and delivers 250 to 300 gallons per minute. Both pumps are run by a 15-horsepower portable engine, using naphtha for fuel. The total cost of both plants was $1,200. The main canal is 800 yards long, has a cross section of 4 square feet, and will deliver 1,000 gallons per minute. Its cost was $75. The cost of maintaining canals and laterals is $25 per annum. The furrow system of irrigation is used and the irrigation period lasts six months. From 4 to 24 inches of water are applied per season, depending upon the kind of crop and the rainfall, which is estimated to be 5 to 15 inches during the irrigation season. Forty acres were under cultivation in 1908, and it will be the same for 1909; only 60 acres can be served by this canal. Unimproved lands before irrigating are valued at $40 per acre, while those under irrigation are valued at $100. It is estimated that it costs $5 per acre to prepare the land for irrigation. The crops grown are cotton, corn, sweet potatoes, Irish potatoes, tomatoes, onions, and melons. These are marketed in Lampasas. Corn yields 40 bushels per acre; cotton, 1 bale; sweet potatoes, 300 to 400 bushels. It costs $15 to $150 per acre to produce and market the crop, depending upon the kind of crop grown, and the average value of the crop varies from $30 to $300 per year for the same reason. The net returns per acre from sweet potatoes is from $100 to $200; cotton, $25; corn, $15; onions, $150 to $200; and Irish potatoes, $50 per acre. With help in harvesting, one man can handle 10 acres of sweet potatoes, 15 acres of Irish potatoes, 40 acres of corn, 40 acres of cotton, and 5 acres of onions. It is estimated that to install a pumping plant for 10 acres and to purchase team and tools, together with running expenses, would require $2,000. The opportunities for settlement are good and perhaps 50 families could be provided room. One hundred and fifty acres will be irrigated in the vicinity in 1909, and the ultimate irrigable area is estimated at 1,000 acres.

The San Jose Irrigation and Power Company.—This company diverts water from Dove Creek at Knickerbocker by means of a brush and rock dam which cost $200 to construct and $100 per year for repairs. This is owned jointly by the landowners along its line, and irrigation is used to supplement the rainfall. From 6 to 8 cubic feet per second is carried by the canal and 1,500 acres could be irrigated if the water supply were sufficient. The main canal is 5 miles long

and the laterals 2 to 3 miles long. The canal slopes 2 to 3 feet per mile and the laterals 3 or 4 feet. The cost of construction is unknown, but the annual cost of maintenance is $100 to $200. The lands are irrigated once every two weeks and the rent for same is included with land rent. The irrigation period lasts from March 1 to October 1, and sometimes grain and alfalfa are irrigated in winter. It is estimated that a depth of 12 inches of water is applied per irrigation. One thousand acres were irrigated in 1908 and the same acreage for 1909, but 1,500 acres could be brought under canal. The present value of unimproved lands is $10 to $15, but before irrigating it was only about $5. Irrigated lands are valued at $50 per acre and the cost of preparing land for irrigation is $10 per acre. The crops and average yields are stated as follows: Alfalfa, 3 to 4 tons; Johnson grass, 2 tons; corn, 40 bushels; cotton, three-fourths bale; oats, 40 bushels. Garden truck yields were not obtainable. The average values of the crops are given: Alfalfa, $50 per acre; Johnson grass, $20; corn, $20; cotton, $35, and oats, $16. It is estimated that one man can care for 20 acres, but there are no opportunities for additional settlers in the immediate vicinity, as no prospect for additional irrigated areas is in sight on account of lack of water.

C. B. Metcalfe, of San Angelo, does not describe his irrigation system in detail, but he irrigates 200 acres at the Gardner dam. He gives a general description of the methods used in diverting the water upon the land and information as to values, etc., and follows with a list of irrigators and acreages in the San Angelo region in 1908. The following is an abstract of his general description: The systems listed as being on the South Concho and Dove creeks are in Tom Green County; those on Spring Creek at Sherwood are in Irion County. Water is diverted from these streams by means of dams built of rock and of concrete. The head gates are set in simple rock abutments, the gates being of wood. The cost of maintaining these is small and the cost of dams, headworks, and ditches will approximate $8 per acre irrigated. Pumping plants consist of centrifugal pumps varying in size from 6 to 10 inches and working against lifts which vary from 20 to 40 feet. In the main they are driven by gasoline engines, but a few steam engines are used. The canals average 7 feet wide and are 3 feet deep, though cuts as deep as 8 feet exist in places. The depth of water will average 2 feet, and the general fall is 3 feet per mile. The canals vary in length from 1.5 to 5 miles and in general follow the edges of the hills, so as to command the areas lying between them and the streams. The cost of maintaining and cleaning canals will average $2 per acre irrigated per annum. No measurement of water is made and farmers receive water in rotation. The average water rental is $3 per acre, and the irrigation season lasts from March to

September. Water is turned on the lands five times per season for field crops and seven times for truck. The average rainfall during the irrigation season is estimated to be 16 inches. The area irrigated during 1908 was 6,200 acres and there will be no increase during 1909. A large additional acreage could be irrigated if the water available were not already appropriated. Storage reservoirs could be constructed, however, and thus the acreage would be greatly increased.

Unimproved lands are worth $20 per acre and the cost of bringing the land under irrigation averages $10 per acre, after which the land is worth $30 to $200 per acre. The crops grown, with their average yields, are as follows: Cotton, 1 to 1.5 bales; corn, 40 bushels; oats, 65 bushels; alfalfa, 4 tons; truck (all vegetables, celery, and melons), about $150 per acre. The cost of producing some of these crops is given as follows: Hay, $4 per ton; cotton, 5 cents per pound; truck, $100 to $150 per acre. The average area which one man can handle is stated as 10 to 40 acres, and for this, in addition to the first cost of the land, $1,500, he would need for other improvements and maintenance for one year $3,500. The opportunities for settlement are good for dairy, truck, and hog farmers, cotton growers, etc. Probably 5,000 responsible white farmers could find good homes. Mr. Metcalfe adds that irrigation has not been very profitable on the large farms on account of the lack of good labor and the high prices. Small tracts have paid well, truck lands yielding $50 or more per acre, net, and alfalfa as much as $40, net. The small farmers do well, and fruit and celery can be very profitably grown in the valleys. The country is a rolling limestone formation and one of the most healthful in the United States. The elevation is 2,000 feet and upward. There are many good springs and an abundance of excellent underground water.

The following list of irrigation systems falling under Group V was compiled from U. S. Geological Survey, Water-Supply and Irrigation Paper No. 71, except as shown in footnotes:

Irrigation systems, Group V.

Owner or company.	Locality.	Source of water.	How introduced into canal.	Lift in feet.	Length of main canal.	Cost exclusive of lands.	Acres cultivated.	Crops raised.
Byers systems	Menardville	San Saba River	Dam					Grapes.
Wilkinson system	do	Clear Creek	do				12	Corn, cotton, oats, etc.
Striegler system	do	do	do				18	Do.
Noyes system	do	San Saba River	do				2,000	
J. C. Petmecky [a]	do	do	do					
Kitchen ditch	do	do	do		4½ miles		300	
Vanderstrucken system	do	do	Pump	31		$1,500	1	
Sloan system	Sloan	Springs	Dam				186	Corn, cotton, cane, potatoes.
Doran system	San Saba	San Saba River	Pump	28			100	Do.
West & Burnett	do	Drain	Dam			1,000		Ordinary crops.
King system	do	Springs					40	Do.
Ellis system	do	Well	Pump	25				Do.
Hawkins system	do	do	do	33		825	50	Do.
Maxwell system	do	Springs			1,500 feet		40	Onions, corn, etc.
Baker system	Sloan	Richland Spring	Dam	20	2 miles		150	Cotton.
Finland system	Lampasas	Lampasas River	Dam and pump				15	Truck.
Swinder Pecan Orchard Co	Brownwood	Pecan Bayou	Reservoir and pump				55	Pecans.
Fairland farm	do		Pumps			5,000	400	Cotton.
Williams or Joe Glenn ditch	Water Valley	North Concho River	Dam		3 miles		225	Cotton, sorghum, oats.
Glenmore ditch	San Angelo	South Concho River	do		4 miles	6,000	110	Celery, alfalfa.
Bismark ditch	do	do	do		do	5,000	600	Oats, corn, cotton, hay.
Gardner system	do	do	do		2 miles	900	70	Do.
Twin Mountain ditch	do	do	do		3 miles	2,500	300	Do.
Metcalfe ditch	do	do	do		4 miles	3,300	470	Oats, corn, and cotton.
South Concho Irrigation Co	do	do	do		3 miles	1,800	220	Oats, hay.
San Jose Irrigation Co	Knickerbocker	Dove Creek	do		6 miles	3,000	1,400	Oats, corn, cotton, sorghum.
Baze ditch	do	do	do		3 miles		160	Oats, alfalfa, cotton.
Kelley system	San Angelo	Lepan Creek	do		1½ miles	450	40	Oats, hay, truck.
Moos system	Junction	Johnston Fork of Llano River.	do		¼ mile		18	Oats, wheat, potatoes, truck.
Rembold system	do	do	do		900 feet	85	4	Truck, Johnson grass.
Long system [b]	do	do	Pumps operated by water wheel.		600 feet	340	5	Truck and sorghum.
Armstrong system	do	do	Dam			1,200	65	Alfalfa.
Allen & Kelly system	do	Cedar Creek	do		¾ mile		20	Wheat, oats, corn.
Jarvis Hodges	do	do	do		800 feet		44	Corn, potatoes, etc.
Taylor place	do	do			2 miles	325	7	Do.
Jenson system	do	Bailey Creek	Spring				5	Corn, cane.
Dupuy system	do	Kyae Creek	do				7	Do.
Griffith system	do	do	Dam				16	Corn, wheat, truck.
Bishop system	do	do				160		Corn, cane, cotton.
Calentine system	do	do				105	25	Corn.

Flemming system	do	Flemming Branch			½ mile	100	35	Corn, oats, alfalfa, truck.
Baldwin system	do	South Llano River	Spring				2	Corn, cane.
Taylor system	do	Christmas Spring	do				25	Do.
Barrett & Stephenson system	do	Springs	do			200	25	Corn, cane, wheat.
Huffman system	do	do	do		300 feet	75	7	Corn.
Hall system	do	East Bear Creek	Dam		½ mile	400	10	General crops.
Reid system	do	West Bear Creek	do		do	60	8	Do.
Stewert system	do	do	do			200	30	Do.
Morales system	do	do	do		¾ mile	275	10	Do.
L. C. Pasture system	do	do	do		⅛ mile	75	8	Alfalfa.
Meng system	do	Walnut Creek					1	Truck.
Gordon system	do	North Llano River	Pump	35		1,800	35	Corn, alfalfa.

[a] Listed in U. S. Geol. Survey, Water-Supply and Irrigation Paper No. 71 as Sieker system.
[b] Sold to J. J. Bullard.

GROUP VI.

The Pecos and Toyah valleys and Fort Stockton regions are embraced in Group VI.

Zimmerman irrigated lands.—Mr. D. Zimmerman, of Kansas City, Mo., owns 27 alternate sections of land in the Pecos Valley and is constructing a canal which has the intake 3 or 4 miles below a point opposite Grand Falls. The canal will follow pretty close to the Pecos River, but, except for a map in the printed prospectus issued with the view to selling lands, no data could be obtained. This prospectus states that lands are offered for $30 per acre on easy payments, and that there will be no charge for water to purchasers now or at any future time. The canal is now under construction and will not be ready to deliver much water during the season of 1909. It is situated on the right bank of the Pecos River, between the river and the canal system to be described next.

The Imperial Canal.—This canal is being projected by the land department of the Kansas City, Mexico and Orient Railway Company. The company has purchased the canal and rights of the Pecos River Irrigation Company and will repair the headworks and a portion of the canal through which to furnish water to the new system. The dam, built of rock and brush, is located in the river 28 miles below Pecos city. From here the old canal will be used for some distance, but farther south the new one will leave it and run to a reservoir. This reservoir is mostly a natural depression on rather commanding ground, and by constructing a low levee on the south end, about 15,000 acre-feet of storage capacity can be secured. From the reservoir the canal will follow a grade contour south and east for 20 miles, and will cover, if water proves available, 100,000 acres of land lying between it and the river. The land under this canal is very uniform, has good slopes for irrigation, and the soil is a dark, rich, silty loam, capable under careful irrigation and thorough cultivation of producing large returns. It is the purpose of the company to use the stored water to furnish the supply during times of shortage only, the principal drought occurring in March and April.

The Grand Falls Land and Irrigation Company.—A brush and stone dam, 150 feet long and 12 feet high, diverts water from the left bank of the Pecos River at Grand Falls; the cost of the dam was $3,500. The main canal is 40 miles long, has 16 feet bottom and 1.5 to 1 side slopes, and falls 1.5 feet to the mile. It cost $1,000 per mile. There are 100 miles of laterals, with bottom widths of 6 to 10 feet, side slopes 1.5 to 1, and the cost of construction varied from $250 to $500 per mile. The annual cost of maintaining canals and laterals is $5,000. Water is not measured, and the land is flooded to a depth of 4 inches to 2 feet at each watering. This excessive

use of water is rapidly destroying the fertility of the land. The rental rate is $1.25 per acre, and irrigation lasts all the year. There were 7,500 acres under cultivation in 1908; it was expected that 8,000 acres would be irrigated in 1909, and the ultimate acreage which this canal can serve, if sufficient water is available, is placed at 30,000 acres. Unimproved land before irrigation was valued at $1.50 and is now valued at $10, while land under irrigation is valued at $50 to $100 per acre. Extra heavy yields of alfalfa, cotton, milo maize, oats, barley, corn, and grapes are obtained from this irrigated land. The value of the yield from an acre of cotton is placed at $50; corn, maize, and oats at $30; alfalfa, $60; and grapes, $500. These are marketed at Monahans, on the Texas and Pacific Railway. The equipment needed for each 40 acres is estimated at $400, and one man is supposed to care for 50 acres of cotton, or 40 acres of alfalfa, or 10 acres of grapes. The average per man is put at 40 acres, and if industrious the beginner can make a start on $1,500. The opportunities are good for 500 families of new settlers.

The Barstow Land and Irrigation Company.—This canal was begun by George E. Barstow, in 1892 or 1893, and diverts water from the right bank of the Pecos River by means of a brush dam situated about 7 miles above the town of Barstow, the inflow to the canal being regulated by a simple wooden head gate. Three miles below the headworks the main canal crosses the Pecos River by means of a wooden flume, and one lateral follows down the west side of the river, watering 800 acres in 1908. The main canal on the east side extends 9 miles down the valley, with many laterals, and in 1908 watered 8,000 acres. The main canals and laterals approximate 70 miles in length. The main canal has a width of 20 feet at bottom, 2 to 1 side slopes, and is 4 feet deep. The grade is 1 foot per mile. The ultimate area which can be served, if sufficient water is available, will approximate 25,000 acres.

Alfalfa and cotton form the principal crops, but in 1908 there were about 200 or 300 acres of milo maize under irrigation and 300 acres in peach and apple orchards and in vineyards.

The town of Barstow was founded in 1894 and has a population now of approximately 1,000, while the whole population supported by the canal system, including the town, is 2,300. Improvements in the water supply of the town are now being made, and an extensive drainage system, under provisions of the new drainage law, is in process of preparation. Land with water right sells at $40 to $100 per acre, and when under cultivation for $60 to $150. The Pecos Valley soil is composed of rich, heavy, black silt for a distance of perhaps 3 miles from the river to the east and 1 mile to the west. Back from the river from 1 to 3 miles the land begins rising quite

rapidly and the surface soil is underlaid at a depth of 1 to 3 feet with a rotten limestone gypsum rock. Elberta peaches, apples, and European grapes, quantities of cantaloups, plums, truck, alfalfa, milo maize, and cotton are grown, bringing large profits when properly cared for.

Irrigation from springs around Fort Stockton.—At Fort Stockton, the county seat of Pecos County, 30 miles west of Grand Falls, springs unite to form Comanche Creek, which has a total discharge of 60 to 70 cubic feet per second, sufficient for 10,000 acres. On 7–D ranch there was irrigated in 1908, 900 acres in Johnson grass. Though the soil of this ranch is a rich silt loam, it produces but small return on account of the very slack methods used in irrigation and cultivation.

Mr. James Rooney irrigated from these springs about 700 acres in alfalfa, corn, and fruit during 1908, and could irrigate much more, as there is plenty of water for a larger acreage, and he expects to increase the area under irrigation to 2,000 acres in 1909. On the 7–D and Rooney ranches a total of 10,000 acres can be irrigated.

J. H. Crawford irrigated 500 acres in 1908 from San Pedro springs, of which 300 acres were in alfalfa, 100 in milo maize, and 100 in corn, truck, etc. He let 200 acres of his second crop of alfalfa go to seed and thrashed 225 pounds of seed per acre, which, at the present price of such seed, is worth $6,750 gross. In addition to this, the straw remains, besides the hay from the first cutting and probably two more after the crop of seed. Alfalfa brings $10 per ton and averages 1 ton per acre to the cutting. By proper cultivation with a disk renovator after each irrigation the yield is increased and alfalfa then needs to be replanted only once in ten or twelve years.

The Fort Stockton country has a rich chocolate loam soil, 2 to 10 feet deep, and contains a large percentage of organic matter. There is sufficient water supply in that region to irrigate about 10,000 acres.

The Toyah Valley Irrigation Company is located at Brogado, Reeves County. The valley, hemmed in by a horseshoe-shaped curve of the Davis Mountains, is a flat which is watered by springs which unite to form Toyah Creek. The valley is 40 miles southwest of Pecos, and 30 miles from Toyah station on the Texas and Pacific Railway. Seven thousand acres are watered from the San Solomon, Saragossa, San Dio, and Little Giffin springs, of which 1,200 acres are in alfalfa, 2,000 in cotton, 275 in orchards and vineyards, and 3,500 in corn, milo maize, Kafir corn, sorghum, oats, and truck. There are 14 miles of main canal, 6 feet wide on the bottom and 1 to 1 side slopes. The longitudinal slope is 46 feet to the mile, but a layer of soft magnesium limestone in the bottom prevents washing. It is planned to use this fall for the development of water power. Eight

miles below the main spring a concrete dam 8 feet high intercepts seepage water returned to the creek and furnishes 10 cubic feet per second, which is used in irrigating lower down the valley. The soil of Toyah Valley is of four classes: Light sandy, dark sandy, chocolate loam, and black loam. The chocolate loam and the light sandy soil predominate, but all are very rich. There are large areas of this valley which are available for irrigation, provided sufficient water can be conserved by storage reservoirs. On an average alfalfa is cut six times per season, averaging 1 ton to the cutting, and its value is $10 per ton. Mr. Giffin, who had 35 acres in pear orchard in 1908, states that the previous year he cleared $900 per acre on Kieffer pears.

GROUP VII.

Group VII covers the Rio Grande Valley in the vicinity of El Paso and as far down the river as Presidio and Brewster counties.

Franklin Irrigation Company.—This company owns and operates the principal system in the El Paso Valley. Water is diverted from the Rio Grande just above El Paso, and the main canal is 28 miles long, 20 feet wide at the bottom for a distance of about 5 miles from the intake, after which it decreases to 16 feet bottom width. The side slopes are 2 to 1, the depth 4 feet, and the capacity at the intake 300 cubic feet per second. The company owns no laterals, as the consumers are required to construct those which are necessary to reach their lands. This system covers 5,000 acres, planted to alfalfa, grain, fruits, and vegetables. The water rental is $3 per acre for truck and $2 per acre for other crops. The canal system is divided into 4 sections of 7 miles each, and a tender is assigned to each section whose duty it is to distribute the water by rotation, making a round once in ten days.

Socorro and San Elizario ditches.—These are community canals, each serving 1,600 acres. On account of the changes in the river they are not able to receive water from the river at all times, but in case of shortage from this source they draw water from the Franklin Canal. The crops grown are the same in character as those cultivated on the Franklin system. The soil of El Paso Valley varies from a fine thick sand to a heavy silty clay, rich in mineral plant food but lacking in humus. On account of the altitude—3,500 feet above sea level—the clays under proper handling are especially well adapted to the production of fruit, particularly the Bartlett pear. In the valley alfalfa yields 5 to 10 tons, which is worth $10 per ton; wheat produces 30 to 40 bushels to the acre; sweet potatoes yield 300 bushels to the acre and are worth 2 cents per pound; Bartlett pears yield 500 to 600, occasionally as many as 1,000, 50-pound boxes, worth $1 to $1.50 per box, and the net returns vary from $200 to $500 per acre.

The limits of El Paso extend 4 to 5 miles east of the main portion of the city, and within these limits land for irrigation and other purposes sells as high as $1,200 per acre. From 6 to 10 miles down the river the land sells for $100 to $150 per acre, and 10 to 12 miles below El Paso it sells for $100 per acre. The present irrigated area, together with a large additional acreage, amounting in all to 45,000 acres, will come under the Rio Grande project of the Reclamation Service. This system of canals is now under construction.

The following systems, situated in the Big Bend of the Rio Grande, are mentioned in a publication of the U. S. Geological Survey.[a]

Systems in the Big Bend of the Rio Grande.—The Candalereia ditch takes water from the Rio Grande at a point 45 miles from Shafter, when there is water in the river; but ordinarily the canal is fed by Coyote Creek and 200 acres are served.

The Dawson system, at Shafter (G. S. Dawson, owner), utilizes a strong spring to irrigate a small area.

Del Rosa ditch takes water from the Rio Grande, using a low diversion dam for the purpose. One thousand two hundred acres are irrigated.

The Palvo Irrigation Company has a small diversion dam about 10 miles above Presidio. No acreage is given.

The Ernst and Lindsey systems are 2 small private ditches, situated near Boquillas on the Rio Grande, in Brewster County. No acreage was given for the first system, but the latter had 30 acres in beans and corn in 1902.

Alamo and Leoncito Creek systems, on Alamo Creek, in Brewster County, were in operation in 1902, the first of which served 250 acres in corn, beans, wheat, and sorghum in 1902. Three small ditches, irrigating 3 acres each, are mentioned as being taken from Leoncito Creek.

The Pool ditch, near Shafter, was used to irrigate 5 acres in vegetables and fruit in 1902, the water being derived from springs.

The Hoosier Brothers' ditches, near Dryden, were used by Hoosier Brothers to irrigate 24 acres with water derived from a spring.

Jeff Davis County ditches, along Limestone Creek, irrigated 100 acres in farms and gardens in 1902.

Templeton system, 13 miles northwest of Alpine and 15 miles southeast of Fort Davis, irrigates an 18-acre orchard, the water being derived from 2 springs. Two miles above the Templeton ranch a field of hay was irrigated directly from springs without the use of ditches; 30 acres were served.

The above data are six years old.

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[a] U. S. Geol. Survey, Water-Supply and Irrig. Paper No. 71.

LAWS GOVERNING THE CONTROL AND USE OF WATER.

On February 10, 1852, the fourth legislature of the State of Texas passed an act (title 55, chapter 1, Irrigation, Revised Statutes, articles 2982 to 2988) giving to commissioners' courts the right to regulate irrigation and the manner of constructing irrigation systems and appurtenances when the same were situated outside of a corporation having jurisdiction over them. Further authority to establish police regulations and to impose fines for abuse of systems, etc., was given by the same act. Further authority to lease any lot or subdivision on an irrigation system was given in case of delinquency on the part of any owner who failed to pay his proportion of labor and expense for any part of construction or maintenance of the system. The commissioners' courts were also authorized to license private enterprises and to permit the damming of streams and construction of canals for the purpose, provided that "the assurance and the proper security (be) given to the county, if required by said court, that no injury will result to the public health," and providing for suits for injuries to other parties by reason of the construction of the particular irrigation system. The commissioners' courts were authorized also to permit the condemnation of the necessary property over which canals, which in their judgment were of sufficient importance, would pass, or for the construction of the necessary dams, etc. In case of injury to the public health by reason of lakes or other standing water, the commissioners' courts were empowered to order the discontinuance of any irrigation system causing such injury. The courts were authorized also to establish such fence laws as were deemed necessary in the several districts.

On August 21, 1876, the fifteenth legislature passed an act granting to any "person, firm, or corporation who shall construct a canal or ditch for navigation or irrigation, in accordance with the provisions of this chapter," grants of public lands, as follows: For a canal of the first class, which is defined as one carrying a stream of water of a uniform width of 30 feet and uniform depth of 5 feet, 8 sections of land—5,120 acres—for each mile of canal constructed; for the second class, those carrying a stream of water of a uniform width of 15 feet and having a uniform depth of 4 feet, 6 sections per mile; for the third class, those carrying a stream of water of the uniform width of 9 feet and a uniform depth of 3 feet, 4 sections to the mile. Canals or ditches not complying with the conditions of the third class, but carrying streams of water of a uniform width of not less than 6 feet and having a uniform depth of not less than 2 feet, were put in a fourth class and for their construction grants of 2 sections per mile of canal were allowed. Canals for navigation having a width of 40 feet and a permanent depth of 4 feet were granted 16 sections per

mile. (Note that no mention is made of the carrying capacity of any one of the four classes of irrigation canals or ditches named.)

Under the terms of this act the governor was charged with the appointment of an inspector of canals, whose compensation was fixed at $25 per mile of canal inspected, which was to be paid by the firm or corporation doing the building. The builder was required also to furnish a bond to the commissioner of the general land office of the State that the canal would be maintained in good condition for ten years.

The foregoing is covered in articles 2989 to 2995, inclusive, which articles, together with article 3001 providing that no subsidy should be given for unnecessary ditches, were repealed by an act of the seventeenth legislature on April 22, 1882. This act also repealed all laws or parts of laws granting subsidies for the construction of railroads. Articles 2996 to 3000, inclusive, of the act of August 21, 1876, remain in force. These effective articles gave to irrigation or navigation companies a right of way not to exceed 100 feet in width over all public, university, school, and asylum lands, and the use of necessary rock, gravel, and timber for construction purposes. Also the right to cross private lands by contract with the owner, or by condemnation proceedings. The legislature reserved the right to control the rates for freight and passage and for the water supply of cities and towns. It gave also to such companies the free use of the waters of the rivers and streams of the State, but held the companies responsible to injured owners for all damages resulting from the construction of the navigation or irrigation canal. The right to cross highways when necessary was given also, but the constructing companies were required to construct and maintain all necessary bridges for the accommodation of the public.

By acts of March 19 and July 6, 1889 (chapter 3, title 55, Irrigation, Revised Statutes) the diversion of unappropriated running water was authorized when found necessary for irrigation, provided riparian owners were not thereby deprived of water for domestic purposes. Provision was made for the appropriation of public streams for irrigation, and provided for the forfeiture of the right whenever the water was no longer used for this purpose. Regarding priority of right the act states: "As between appropriators, the one first in time is the one first in right to such quantity of the water only as is reasonably sufficient and necessary to irrigate the land susceptible of irrigation on either side of ditch or canal." The process of appropriation was very simple and consisted in filing with the county clerk a sworn statement setting forth the name of the canal, location of headgate, cross section, and capacity of the ditch, the name of the stream from which the water was to be taken, time of beginning work, and the names of the owners, together with a map showing the location

of the canal. The result was the filing of some remarkable documents, some of which claimed several times the total discharge of the streams upon which the canals were to be located, and even stated the discharging capacity at so many "square feet every second." Fortunately, a number of these projects never made any substantial progress beyond the filing of the documents. Others necessarily proved failures. The time of beginning construction was fixed at ninety days from the filing of the statement, and by compliance with the provisions of the act the claimant's right to the use of water dated back to the time of beginning construction. It was made unlawful for subsequent claimants to deprive prior claimants of the use of water except for domestic purposes.

Authority was given for the formation of irrigation companies under the general incorporation laws of the State, and as much as 100 feet width of right of way was granted across all public, university, school, and asylum lands, and condemnation proceedings authorized for the acquisition of right of way across private lands. It was provided that all unused water should be conducted back to the original stream and a crude method of providing for the sale of water was described. The right of the legislature to control the diversion and distribution of water was reserved, this right to be applied either by direct legislation or by the creation of a water commission having full delegated powers.

The right to cross or run along roads and highways was given and it was a misdemeanor for any person to injure any irrigation canal, well, or appurtenance, or to waste the water therefrom or use it without authority. Irrigation corporations were given the right to acquire land either by purchase or donation, or in payment of stock or water rights and to dispose of this at will, and to borrow money, in security for which mortgages on the property of the company would be legal. Also the right to issue bonds was given. It was provided, however, that all lands acquired by such a company, except such as were used for the construction and maintenance of the system, should be alienated within fifteen years of their acquisition or be subject to judicial forfeiture. All conflicting laws or parts of laws were repealed by this act.

The following discussion of the legislative act of 1895 was prepared by Judge W. H. Wilson, of Houston, whose experience in connection with litigation affecting irrigation renders him especially well prepared to emphasize the essential features of the legal status of irrigation in Texas:

> The most important statute in the State of Texas is found in chapter 2, title 60, of the Revised Statutes: Article 3115 declares the unappropriated waters of the ordinary flow or underflow of every flowing river or natural stream and the storm or rain waters of every river or natural stream, canyon, ravine, depression, or water-

shed within those portions of the State of Texas, *in which by reason of the insufficient rainfall or by reason of the irregularity of the rainfall irrigation is beneficial for agricultural purposes* to be the property of the public and subject to appropriation for the uses and purposes named in the statute. By articles 3116 and 3118 it is provided that such waters may be appropriated for the purposes of irrigation, mining, milling, and construction of waterworks for cities and towns and stock raising in such sections of the State. By article 3117 it is provided that such waters shall not be diverted for the purposes named "to the prejudice of the rights of the riparian owner without his consent, except after condemnation thereof in the manner provided in the act." By article 3119 it is provided that as between the appropriators, the first in time is first in right.

By article 3120 it is provided that "every person, corporation, or association of persons who have constructed or may hereafter construct any ditch, canal, reservoir, dam, or lake for the purposes named in this chapter, and taking the water from any natural stream, storage reservoir, dam, or lake, shall within ninety days after commencement of such construction, file and cause to be recorded in the office of the county clerk of the county where the head gate of such ditch or canal may be situated or to which said county may be attached for judicial purposes,in a well-bound book to be kept by said clerk for that purpose, a sworn statement in writing showing approximately the number of acres of land that will be irrigated, the name of such ditch or canal, the point at which the head gate thereof is situated, the size of the ditch or canal in width and depth, and the carrying capacity thereof in cubic feet per second of time, the name of said stream from which said water is taken, the time when the work was commenced, the name of the owner or owners thereof, together with a map showing the route of such ditch or canal; and when the water is to be taken from a reservoir, dam, or lake, the statement above provided for shall show in addition to the ditch and other things provided for, the locality of the proposed dam, reservoir, or lake, giving the names or numbers of the surveys upon which it is to be located, its holding capacity in cubic feet of water, the acreage and surface feet of land that will be covered, and the limits of such lake, reservoir, or dam, and the area of the watershed from which the storm or rain water will be collected."

Article 3121 provides that by compliance with the provisions of article 3120 the claimant's right to the use of the water relates back to the time when the work of excavation of construction commenced.

Article 3122 provides that "any person, firm, association of persons, or corporation may acquire the right to appropriate for irrigation purposes the unappropriated waters of the ordinary flow or underflow of every running or flowing river or natural stream, and the storm or rain water of every river or natural stream, canyon, ravine, depression, or watershed within those portions of the State referred to in article 3115, by filing a sworn statement in writing to be recorded as provided in article 3120, declaring his or its intention of appropriating such water. Said statement shall also show approximately the number of acres of land proposed to be irrigated, the name of such ditch or canal, the point at which the head gate thereof will be situated, the size of the ditch or canal in width and depth, and the carrying capacity thereof in cubic feet per second of time, the name of the person, firm, association, or corporation appropriating such water, the name of the stream, and shall attach to such statement a map showing approximately the proposed route of such ditch or canal; and when the water sought to be appropriated or acquired is storm or rain water, the statement above required shall show or describe also the locality of the proposed dam, reservoir, or lake by giving the names or numbers of the surveys upon which it is to be located, and approximately the following, that is to say, its holding capacity in cubic feet of water, the acreage of land that will be covered, and the area of the watershed from which the storm or rain waters will be collected; provided, any person, association of persons or corporation who has heretofore had a survey made of the proposed route

of his or its ditch shall have a preference right at any time within ninety days from the time this chapter shall take effect to file the statement hereinbefore required for the appropriation of water. Within ninety days next after filing of said statement the party or corporation claiming the right to appropriate the water shall begin actual construction of the proposed ditch, canal, dam, lake, or reservoir, and shall prosecute the work thereon diligently and continuously to completion."

Article 3123 provides that by "completion" is meant the conducting of the water in the main canal to the place of intended use. Article 3124 provides that the person or corporation who has appropriated such waters in accordance with the statute shall be entitled to the exclusive use except that an owner whose land abuts on a running stream may use such water therefrom as may be necessary for domestic purposes, and except that a person owning land on the watershed from which the waters were collected may construct such dams, etc., as are necessary for the storage of water for *domestic* purposes. By article 3125 it is provided that—

"Corporations may be formed and chartered under the provisions of this chapter and of the general corporation laws of the State of Texas, for the purpose of constructing, maintaining, and operating canals, ditches, flumes, feeders, laterals, reservoirs, dams, lakes, and wells, and of conducting and transferring water to all persons entitled to the same for irrigation, mining, milling, to cities and towns for waterworks, and for stock raising, and for the purpose of building storage reservoirs for the collection and storage of water for the purposes before mentioned. All such corporations shall have full power and authority to make contracts for the sale of permanent water rights, and to have the same secured by liens on the land or otherwise, and to lease, rent, or otherwise dispose of the water controlled by such corporation for such time as may be agreed upon, and in addition to the lien on the crops hereinafter provided for, the lease or rental contract may be secured by a lien on the land or otherwise. All persons who own or hold a possessory right or title to land adjoining or contiguous to any canal, ditch, flume, or lateral constructed and maintained under the provisions of this chapter, and who shall have secured a right to the use of water in said canal, ditch, flume, lateral, reservoir, dam, or lake, shall be entitled to be supplied from such canal, ditch, flume, lateral, dam, or lake, with water for irrigation of such land, and for mining, milling, and stock raising, in accordance with the terms of his or their contract; provided, that if the person, association, or corporation owning or controlling such water, and the person who owns or holds a possessory right or title to land adjoining or contiguous to any canal, ditch, flume, or lateral constructed and maintained under the provisions of this chapter, fail to agree upon a price for a permanent water right, or for the use or rental of the necessary water to irrigate the land of such person and for mining, milling, and stock raising, such person, firm, association, or corporation shall, nevertheless, if such person, association, or corporation has or controls any water not contracted to others, furnish the necessary water to such person to irrigate his lands, and for mining, milling, and stock raising, at such prices as may be reasonable and just; provided, further, that in case of shortage of water from drought, accident, or other cause, the water to be distributed shall be divided among all consumers pro rata according to the amount he or they may be entitled to, to the end that all shall suffer alike, and preference be given to none. The sale of the permanent water right shall be an easement to the land and pass with the title thereof, and the owner thereof shall be entitled to the use of the water upon the terms provided in his or their contract with such person or corporation, or in case no contract is entered into, then at just and reasonable prices. Any instrument of writing providing a permanent water right shall be admitted to record in the same manner as other instruments relating to the conveyance of land."

Article 3126 grants to the corporations and associations named in preceding article a right of way over public lands and grants right of condemnation of a right of way and land for reservoirs, etc., on and over the lands of private persons.

Article 3128 provides a mode of crossing roads and highways with canals. By article 3130 it is provided that the person, corporation, etc., who leases or rents the water to any person or corporation owning lands subject to irrigation "shall have a preference lien superior to every other lien upon the crop or crops raised upon the lands thus irrigated under such lease or control."

By article 3131 it is provided that a corporation organized for the purpose of irrigation shall have the right to acquire lands by donation or purchase, or in payment of stock or water rights, and to hold and dispose of such land or other property and to borrow money for the construction and maintenance of its canals, reservoirs, etc., and may issue bonds and mortgage its corporate and other property and franchises to secure the payment of any debts contracted for same; provided that all lands acquired by said corporation, except such as are used for the construction, maintenance, and operation of said canals, ditches, laterals, feeders, reservoirs, dams, lakes, and wells, shall be alienated within *fifteen years from the date of acquiring said lands, or be subject to judicial forfeiture.*

By article 641 (section 23) of the revised statutes, private corporations may be formed for the construction, maintenance, and operation of dams, reservoirs, lakes, wells, canals, flumes, laterals, and other necessary appurtenances for the purpose of irrigation, navigation, milling, mining, stock raising, and city waterworks.

There are other provisions of the statute law of Texas affecting irrigation, but they mainly concern details. The above are the more important statutes, and those under which the large irrigating corporations are organized and operating.

In April, 1905, the twenty-ninth legislature passed an act "to provide for the organization and government of irrigation districts, and to provide for the acquisition or construction thereby of works for the irrigation of the lands embraced within such districts, and to issue bonds in payment therefor, as authorized under the constitution, and also to provide for the distribution of water for irrigation purposes, and to furnish water for mechanical purposes; and granting to such irrigation district the right of eminent domain."

This gives in detail the method of organizing such districts under direction of the commissioner's court of the county in which such district, or the greater portion thereof, may lie. A petition signed by a majority of the holders of title in the proposed district is first presented to the commissioner's court, and if the court decides that the case comes within the provisions of the act an election is ordered within the boundaries of the proposed district. If two-thirds of the votes cast by legally qualified voters, who at the same time are resident property taxpayers in the district, are in the affirmative, the court enters an order to the effect that the district has been organized. At the same time that the above-named election is being held a board of directors, an assessor, tax collector, and treasurer are chosen also, and it is the duty of these officers to conduct the business affairs of the district. This act covers 25 printed pages, mostly relating to details of organization, sale of bonds, assessment and collection of taxes for the construction and maintenance of the district organization and irrigation system, etc., and is too extensive to be summarized here. Section 92 of the act provided that this statute shall not

repeal any existing statutes not inconsistent with this act, and that none of the provisions of it shall be construed as applying to water secured from wells.

In 1907 the thirtieth legislature passed an act authorizing the organization of drainage districts along lines somewhat similar to those of the 1905 irrigation act, at least as to organization and issuance of bonds, but providing a different method for the collection of taxes, and differing in some other details. This act was intended primarily for the relief of the coastal areas which for topographic reasons were deficient in natural drainage. It has application, however, to irrigated areas where there is danger of waterlogging the soil. At Barstow such a drainage district has been formed for the relief of lands irrigated by water from the Pecos River.

THE SETTLEMENT OF LANDS UNDER IRRIGATION SYSTEMS.

The State covers so large an area and the climatic, topographical, and other natural conditions are so varied, and the rainfall so variable and so differently distributed seasonally in portions of the State that it is impossible to give average values of the labor and expense necessary on the part of the settler to prepare the land for water and to establish a home which would even approximately apply to all sections, even for the same character of crops. It has been thought best, therefore, to insert the estimates of parties on the ground in each description of an existing or projected irrigation system, wherever such data could be obtained. While some of these are mere guesses, others are carefully made by competent irrigation men and the inquirer must judge of the value for himself. In most sections of the State labor is scarce and the daily wages quite variable. Along the Mexican border labor can be secured at small cost, generally about 50 to 62.5 cents per day without board. In the central and eastern portions of the State as much as $1.50 per day is frequently paid, though generally $1 per day or less would cover ordinary conditions. The higher price is generally paid during cotton-chopping season, when every day counts.

COST OF CLEARING AND PREPARING LAND FOR IRRIGATION.

The cost of preparing land for cultivation, either with or without irrigation, can not be given so as to represent a reasonable average for the whole State because of the wide variations in natural conditions. The cost per acre for clearing in timbered regions may be offset by the value of the timber in some localities, while in others this must be burned to remove it from the ground. With many mesquite roots to be grubbed out, the cost in some sections may be $10 or more per acre for this alone. No attempt is made here to estimate average costs of this character, and the inquirer is referred

to the answers given under the descriptions of existing and projected irrigation systems. The following cost of clearing and preparing land was the actual cost for a tract near Mercedes, and is a fair average of the cost of such work in the Rio Grande Valley:

Clearing land of timber:		
Contract price per acre of clearing timber and brush	$10.00	
Extras—		
Cutting timber into cord wood, 5 cords at 37.5 cents per cord	1.88	
Cutting timber into posts, 25 posts at 2 cents each	.50	
Cutting timber into railroad ties, 1 tie per acre, at 20 cents	.20	
		$12.58
Returns from sale of timber per acre:		
5 cords of wood	5.00	
25 posts	3.75	
1 railroad tie	.50	
		9.25
Actual cost of clearing timber		3.33

Cost of clearing land of roots.—In clearing the ground of roots a man and team can plow 2 acres per day. The following were the prices paid in this work per day:

Man	$0.625	
2-horse team and wagon	1.250	
Plowing, team and man	2.500	
Raking and hauling brush, 2 men and team	2.500	
Total	6.875	
First plowing:		
Plowing	$2.50	
Grubbing roots, 5 men	3.15	
Picking up roots, man and wagon	1.87	
Second plowing:		
Plowing	2.50	
Grubbing roots, 3 men	1.90	
Picking up roots, man and wagon	1.88	
Third plowing:		
Plowing	2.50	
Clearing roots, 2 men	1.25	
Picking up roots, man and team	1.87	
Total for 2 acres	19.42	
Total for 1 acre		9.71

Cost of preparing land for irrigation.

Man and team with Shuart grader or leveler, 2 days	$7.00	
Two men, 6 horses, and grader building levees, ⅓ day	2.00	
Building 1 mile of ditch	5.00	
Total		14.00
Clearing timber, roots, and preparing for irrigation		27.04

PRINCIPAL IRRIGATED CROPS.

RICE.

In growing rice under irrigation one man can handle approximately 100 acres up to harvest time. If he is just settling on a leased rice farm about $2,000 in money will be necessary to purchase teams, tools, seed, etc., to employ additional labor from time to time, and to maintain his family until the first crop is harvested. Many have made a success with less capital, while others have failed with more. Reliable men are often able to start with comparatively nothing by securing advances from merchants or landowners, but anyone not known in the community would find it difficult to secure these advances, even by offering to mortgage his stock or crops.

The following estimate of the cost of producing rice and the net returns was made by W. L. Rockwell, of the Office of Experiment Stations. This estimate is based on figures obtained from a number of successful growers and is a fair statement of the cost and returns under ordinary conditions. The average yield is 10 barrels per acre and can be increased. The net returns can be increased 25 per cent or more by intensive cultivation. The average price is $3.50 per barrel. The cost per acre of producing and marketing are itemized as follows:

Plowing	$1.50
Seed	1.25
Sowing	.75
Cultivation	4.50
Building levees	1.50
Irrigation	5.50
Harvesting	5.00
Marketing	2.00
Rent	5.25
Total	27.25
Average net returns per acre	7.75

BEANS.

The following figures as to the cost of raising beans in the lower Rio Grande irrigated area were furnished by W. A. McNeill, secretary-treasurer of the Santa Maria Irrigation Company:

Preparing land	$5.00
Seed, 1 bushel per acre	4.00
Planting	.50
Irrigating, four times, at $1 each	4.00
Harvesting, average of 200 bushels	20.00
Baskets, 200, at 16 cents each	32.00
Marketing—hauling, commission, etc	50.00
Total	115.50

The average yield is 200 bushels, and a conservative average selling price, $1.25 per bushel, gives a gross return of $250 and a net return of $134.50 per acre. Mr. Rockwell, however, states that at the time he was in the district—April or May, 1908—beans were selling at $3.50 per bushel. During May nonirrigated beans were being shipped out of Hempstead, Waller County, at about the same price.

ALFALFA.

One of the best paying crops grown under irrigation, and in some localities without it, is alfalfa. Under favorable climatic conditions, as in the Pecos Valley, it need not be replanted oftener than once in ten or twelve years. The number of cuttings vary from four to eight per season, the second cutting usually being heaviest. The average yield per cutting for a good stand is 1 ton per acre and the selling price varies from $8 to $16 per ton of baled hay, the average being ordinarily between $10 and $12. The cost of production, including baling and hauling to a shipping point, may be put at $20 to $30 per acre as an average. When grown under irrigation the crop does better if thoroughly disked after each irrigation. The same principle applies to nonirrigated alfalfa, the disking following the rains.

John Closner, of Hidalgo County, does not make an itemized estimate of costs or returns, but states that five to seven cuttings per season are obtained from alfalfa lands on the lower Rio Grande, and if these yield as much as 1 ton per cutting it is not difficult to figure large profits. The question of freight rates and the distance to the nearest market should be carefully considered. however, before going in for a crop of this or any other kind.

R. E. Smith, of Sherman, Grayson County, who it is estimated has 1,400 acres of alfalfa, and has been given the title of "alfalfa king," was asked for an estimate of the area planted to alfalfa in the State during 1908. He writes that he was unable to make such an estimate for lack of data. He raises alfalfa successfully without irrigation, but is fortunately situated as to the seasonal distribution of rainfall. Among other things he states in his letter: "I believe, however, that it will be found that there is not so much water needed for alfalfa after all when the meadows are properly cared for." He believes that by harrowing and proper cultivation of the meadows, and the maintenance of a good mulch on the ground the soil moisture can be conserved and irrigation dispensed with, though where the best results are to be attained water at the proper time is essential. He estimates that his extensive meadows will average 5 to 6 tons per annum, one of the cuttings—after the first and before the last—being reserved for seed. He states that this seed brings $9 to $10 per bushel and the yield will run 2 to 6 bushels per acre. Furthermore, the straw from this cutting will more than pay the expense of harvesting

and thrashing the seed. The selling price of alfalfa at the railroad station at Sherman varies from about $12 to $15 per ton. Mr. Smith sells his bright hay during the early part of the season, reserving the discolored hay for home use and for sale in winter when it is scarce, and he usually gets as much for the discolored as for the bright hay.

Mr. Smith states that by plowing Johnson-grass land during July and August a good seed bed for alfalfa is secured and most of the Johnson grass is killed, and if a good stand of alfalfa is secured the remaining Johnson grass will be effectively controlled. He believes, moreover, that about half-and-half alfalfa and Johnson grass make a better-balanced ration than alfalfa alone.

VEGETABLES AND TRUCK.

On the lower Rio Grande Valley, as in the rice district, the new settler will need $2,000 in cash or credit. The area one man can manage depends upon both the man and the crop grown. Truck requires much labor and often one man can tend but 5 acres, or even less. The average cost of producing and marketing cucumbers will run from $96 to $100 per acre. The average crop is about 200 bushels per acre, although 425 bushels have been raised. The average price is $1 per bushel and the average net return is approximately $100 per acre.

The following cost data for onions was furnished by E. C. Dustin, of Mamie, Tex., a station on the St. Louis, Brownsville and Mexico Railway, about 60 miles above Brownsville:

Cost of growing a crop of onions.

Rent of 1 acre of land	$12.00
Preparing 1 acre of land for planting	7.50
Cost of onion sets, from seed bed	2.00
Transplanting about 130,000 plants to the acre	15.00
Irrigating	6.00
Cultivating eight or nine times at 60 cents to 75 cents each	6.00
Topping	8.00
Plowing and picking	3.50
Sorting and crating	4.50
Crates, about 400 to the acre, at 18 cents each	72.00
Hauling to railroad (3 miles)	6.00
Freight and commission	28.00
Interest on $75 at 8 per cent	6.00
Total	176.50

The average yield was given as 400 bushels and the average price at $1 per bushel, leaving a net return of $223.50 per acre. During the season of 1908 onion growers in the vicinity of Laredo suffered severe losses because of the excessive use of water followed by a couple of heavy showers just after the last irrigation. These caused the onions to grow to unusual size, but on account of the excess of water con-

tained they would not stand shipment satisfactorily, and perhaps 25 per cent of the crop was lost. The consequences may prove ultimately to be beneficial, however, as the contemplated acreage for next season was so much in excess of that for 1908 that it would have been difficult at the present time to have procured a satisfactory market for the yield.

FUTURE DEVELOPMENT IN IRRIGATED FARMING.

Between San Antonio and the Rio Grande lie 25,000,000 acres of land, at least three-fourths of which will produce good crops. Through the Trinity, Brazos, Colorado, Guadalupe, and Rio Grande, 20,000,000 acre-feet of water annually flows to the Gulf, which is lost so far as Texas land is concerned. Besides this there are several small streams, as the San Antonio and Nueces rivers, which carry quite a volume during the early portion of the season. To this is to be added the artesian and shallow-well supply. In large sections of the northern and western parts of the State the same unused supply is available in a somewhat smaller amount.

It is impossible to even approximately forecast the future of irrigated farming in Texas, because of the great area of the State and the local variations in climatic and other natural conditions. Already there are upward of 400,000 acres and possibly as much as 500,000 acres under irrigation, and other systems of vast proportions are now in process of construction, besides numbers of small projects. On the lower Rio Grande development on a large scale is now most active, and it is estimated that when the systems now in process of construction are completed it will be possible to serve 180,000 to 200,000 acres or more in that vicinity alone. On the Southern Pacific Railway Company's "Rice Belt" map, David M. Duller estimates that 100 canal systems in Texas listed on that map are capable of covering ultimately nearly 1,200,000 acres, but this includes the Brownsville region and others not now devoted to rice culture. It does not, however, cover the irrigation from wells in the coastal region, nor the central or western districts. If one may judge by present development, it is possible that the area now irrigated may be more than doubled within the next ten years. Many times this area will doubtless be developed in the State eventually, provided the required amount of water can be conserved in the arid and semiarid portions, and even in the humid and semihumid districts the use of water will gradually be extended, not only for rice cultivation, but for the assistance it will render in fruit and truck growing, and even in the cultivation of staple crops. In such cases irrigation will serve as a species of insurance against periods of drought, even though the normal rainfall be sufficient ordinarily for the production of excellent crops. It is estimated that for the year

1907 the melon crop alone brought into the town of Hempstead, 50 miles northwest of Houston, on the line of the Houston and Texas Central Railroad, fully $100,000, and this without any irrigation and on poor sandy land formerly supposed to be worth very little for any purpose. Owing to heavy rains during the spring of 1908 the crop was delayed somewhat and the quality of the melons injured, but Waller County shipped during that year somewhere in the neighborhood of 800 carloads of melons, the number per car varying from 800 to 1,400. These have gone out of Hempstead principally. Because the crop was late and was thrown upon the market in a very short time prices slumped and it is probable that the net returns from shipments did not exceed $50,000 or $60,000. Waller County produces considerable quantities of radishes, beans, cantaloups, etc., as do many other counties of eastern and southern Texas, under natural conditions of rainfall; but with irrigation as an aid in dry seasons a good crop would be practically insured at a time when prices should be good, and even in ordinary seasons it would serve to prolong the season and possibly avoid glutting the market, with consequent depression in prices. In eastern Texas, as in other sections of the humid region, irrigation as an adjunct to natural rainfall should prove beneficial in the cultivation of fruit, vegetables, berries, etc., but it is not so used to any extent in that section, though near Beeville and other places it is practiced.

At a meeting of the Farmers' Congress, held during July, 1908, a resolution was adopted by the Rice Farmers' Association urging upon the legislature the creation of a state water board, or commission, with the particular idea of having this commission regulate land and water rents in the rice-growing districts. The moving cause of this resolution lay in a recent change in the system of land and water rentals by several of the larger canal systems, a fixed charge of $6 per acre for water having been substituted for the usual one-fifth of the crop produced, and a similar charge for land rent. A commission composed of competent men could do much, not only for the benefit of the rice growers but all classes of irrigators as well, and should be empowered to devise a system of equitable water distribution which would tend to conserve the water now available for existing systems and to fix penalties for the violation of promulgated rules. It might well investigate the question of rentals or tariffs on water and on land under irrigation, and also might establish standard rates and fix penalties for the abuse of water privileges, etc. There might, however, be a question as to the advisability of giving so much power to the commission.

At present there appears to be no adequate provision for the settlement of contentions regarding priority of claims to a given water supply, nor for the protection of riparian rights except by appeal to

the courts. The commission might well be empowered to investigate this subject and to recommend suitable legislation, even to the extent of drafting bills to cover the case, which would be submitted to the legislature from time to time for action as seemed desirable. It might be advisable to vest authority in such a commission to devise rules to cover certain phases of the question, and with the power to enforce these rules. There is need also of a state irrigation engineer, to act as advisor to the water commission or to be a member of that board. The collection of statistics and the issuance of circulars of instruction to irrigators should be a part of the duties of the office, and because of the vast area to be covered it might be desirable to establish subordinate or branch offices at several representative points in the State.

In addition to the reclamation of arid lands by irrigation, the problem of drainage in those regions where excessive rainfall or topographic conditions cause the lands to remain covered with water for long periods should be investigated. The need of action along these lines was recognized by the legislature when the present drainage act was passed in 1907. Active steps have been taken in the formation of drainage districts in some portions of the coast country, as at Angleton, Bay City, and perhaps at other points, where the work is practically ready to be gotten under way. At Barstow and Grand Falls, in Ward County, the people have organized drainage districts, for it is beginning to be recognized that even in the arid regions drainage is a valuable adjunct to irrigation, especially where excessive amounts of water have been applied to the land and water-logging of the soil has resulted. In portions of western Texas this excessive use of water has resulted also in bringing the alkali to the surface in such quantities as to injure seriously the productive qualities of the soil, and drainage would benefit such land materially.

While there is still an abundance of fertile arable land in sections where the normal rainfall is sufficient to mature certain crops, the high prices, which tend upward constantly, and the decreasing amount of undeveloped land of this character have a tendency to force development farther westward into regions of smaller rainfall, used heretofore chiefly for grazing purposes. In such regions of greater rainfall it is being demonstrated that many agricultural products not previousiy cultivated can be grown successfully and by the aid of irrigation can be made much more profitable than the old-time crops of corn and cotton.

The day of the large plantation and immense cattle ranch is passing and the number of small farmers is increasing rapidly. These are learning the economic value of growing a variety of products for home consumption. The rapidly increasing population will tend to accentuate the necessity for intensive as against extensive cultivation, all

of which will have the effect of bringing into prominence the importance of irrigation.

At present there is pressing need of systematic instruction in the economical use of water. On the rice lands which have a heavy clay bottom impervious to water, or nearly so, the methods of flooding by checks involves no serious loss by absorption, though there is a growing tendency among rice farmers to use less water than formerly, the check levees now being run so as to have a difference of level of not more than 3 or 4 inches on the average, as against 5 or more formerly. Moreover, the water is not now held so deep upon the upper side of the area inclosed by the levees as was formerly the case. In other types of land having an open, porous subsoil, flooding, especially by the border method almost universally used in the western portion of the State, leads to excessive dosing on the upper side of the area before the water can be made to reach the lower side. Mr. Rockwell states that the measured amount of water applied to one of these borders this season when the water had finally reached the most distant portion of the area was equal to a depth of 5.25 feet over the area. Such wasteful application leads not only to danger of water shortage on some portions of a given system, but also to water-logging of the soil and tends to cause the alkali to rise to the surface, destroying the fertility of the soil. A partial remedy for the wasteful use of water would be to change the rental method from a fixed amount per acre, now so common on systems where many farmers draw from the same canal, to a charge for the actual amount of water used, or for all used over and above a certain quantity per acre for which a flat rate has been fixed. If 1 acre-foot is sufficient for the production of a given crop on 1 acre, the use of from two to ten times that amount not only curtails the area which could be served but injures the land of the irrigator, or that of some one else on lower ground, and results in poorer crops. In some districts a different rental is now required for different crops, an indication of a partial recognition of the variation in the amounts of water required by different growths.

There is urgent need for systematic study of the duty of water for different varieties of crops and in different localities under different conditions as to temperature, rainfall, and evaporation. The "duty" of water is expressed in a variety of ways. Sometimes it is stated as the number of acres per season which will be served by a continuous flow of 1 cubic foot per second; sometimes as the number of acre-feet, or acre-inches, of water required to mature a given crop on 1 acre of land; another expression is found in the depths of water required per season per crop, but this is only another form of the second definition given above.

A single experienced irrigator in each locality could do more in the way of teaching others the proper methods to use in the application

of water to various crops by actual demonstration than could be accomplished by any amount of printed bulletins or even lectures. A good production with a smaller quantity of water than is being generally used would be the very best kind of instruction, for "seeing is believing" in cases of this kind. Steps should be taken to place men of this type on experimental farms in the typical irrigation districts of the State, and if these farms were devoted also to investigation of the best varieties of crops now grown, or the determination of such new ones as could be adapted to the local conditions, great economic value would thereby be given them.

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